LEANER AND MEANER COMPUTERS

highTechnology

COVERING THE BUSINESS OF EMERGING TECHNOLOGY

JUNE 1986
$2.50

TRANSFORMING THE FAMILY CAR

- Engines combine power and economy
- Ride controls deliver safety and comfort

Rethinking space business

The personal computer that continues to raise high performance to new heights.

If you work with high volumes of information, you need answers fast.

Which is why IBM created the Personal Computer AT.® The PC designed to push high performance even higher.

The power of Advanced Technology.

Turn on the power, and you'll notice the advances right away.

To begin with, the Personal Computer AT can compute with astonishing speed. That's something you'll appreciate every time you recalculate a spreadsheet. Or search through a data base.

It can store mountains of information—up to 15,000 pages' worth—with a 30-megabyte "hard file" (fixed disk). And when business gets bigger, you can double your capacity to 60MB with a *second* hard file.

Advanced Technology advances again.

Fast as it is, new models of the Personal Computer AT run up to 33% faster.

Plus, you can now select an enhanced keyboard. It has separate cursor keys, a separate numeric keypad (for easier data entry) and twelve function keys. It also has a main typing section patterned after the classic IBM Selectric® keyboard, which makes word processing easier than ever.

In addition, you can also choose a new option that lets you use 3.5-inch diskettes with your Personal Computer AT.

Family ties.

The Personal Computer AT is compatible with the IBM PC and PC/XT. So it can run many of the thousands of programs written for the IBM PC family.

And with new IBM products, the Personal Computer AT can more easily communicate with other PCs.

IBM's networking options, for example, let you share files from a variety of popular programs.

While the IBM PC 3270 Emulation programs let you retrieve information from a mainframe.

You can also use the Personal Computer AT to run IBM PC XENIX® —an enhanced multi-user, multi-tasking operating system.

A powerful value.

Only the Personal computer AT offers these capabilities *and* IBM's commitment to quality, service and support. A combination that can't be cloned.

Better still, you'll find that the new models offer higher performance without a higher price. And if you qualify, you can conveniently charge your Personal Computer AT on IBM's Credit Card. Or lease one with the IBM Commercial Lease Agreement.

See the Personal Computer AT at an Authorized IBM PC Dealer. Or call your IBM marketing representative.

For the name of a store near you, call 1-800-447-4700. In Alaska, call 1-800-447-0890.

The IBM Personal Computer AT, for Advanced Technology.

Little Tramp character licensed by Bubbles Inc., s.a.
IBM, PC/XT and Personal Computer AT are trademarks of International Business Machines Corporation.
XENIX® is a registered trademark of Microsoft Corporation. Based on System V.

Circle No. 43 on Reader Service Card.

©Copyright IBM Corporation 1986

BREAKTHROUGH: FLOAT AN EYE TO STEADY ITS LENS.

No matter how well protected mobile cameras or telescopes may be, the motion of the vehicle carrying them causes the lenses to jitter and shake. Images are blurred and imprecise.

We discovered a way to make a moving lens sit still. By using high-energy, rare earth magnets, we suspend an electro-optical system in a magnetic field–in effect, make it float. Untouched, it remains steady while its source of transportation vibrates. This "soft ride" assures crisp, unblurred vision for an observer or a sensor.

Army scouts call it the first major advance in mobile observation since binoculars were issued to the cavalry.

We're creating breakthroughs that make a difference in the way things work and the way people live.

We're McDonnell Douglas.

*For more information, write to:
McDonnell Douglas, Box 14526,
St. Louis, MO 63178*

MCDONNELL DOUGLAS

HELICOPTERS SPACE & MISSILES MILITARY & COMMERCIAL AIRCRAFT INFORMATION SYSTEMS HEALTH CARE FINANCING ENERGY

©1986 McDonnell Douglas Corporation

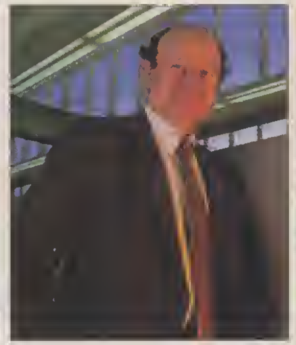
JUNE 1986

highTechnology

VOL. 6, NO. 6

12

28



38

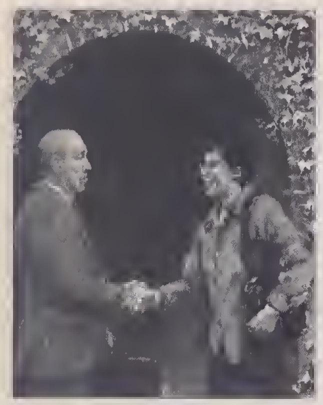
50

FEATURES

DEPARTMENTS

COPYRIGHT © 1986 by High Technology Publishing Corporation. All rights reserved. Editorial and executive offices at 38 Commercial Wharf, Boston, MA 02110. HIGH TECHNOLOGY (ISSN: 0277-2981) is published monthly by High Technology Publishing Corporation, 1642 Westwood Blvd., Los Angeles, CA 90024. Subscription rate for U.S. and U.S. possessions, 12 issues $21, 24 issues $35, 36 issues $42; Canada, 12 issues $26; all other countries, 12 issues $45, payable in U.S. currency. All subscription correspondence should be addressed to David Patterson, HIGH TECHNOLOGY Magazine, P.O. Box 2810, Boulder, CO 80322, 1-800-525-0643. Please allow six weeks for change of address. Include your old address as well as new and, if possible, enclose an address label from a recent issue. Second class postage paid at Los Angeles, CA and additional mailing offices. Postage paid at Mississauga, Ontario. POSTMASTER: send address changes to HIGH TECHNOLOGY Magazine, P.O. Box 2810, Boulder, CO 80322. Material in this publication may not be stored for electronic distribution or reproduced in any form without permission. Request for permission should be directed to Permissions Manager, HIGH TECHNOLOGY, 38 Commercial Wharf, Boston, MA 02110. High Technology is a registered trademark of High Technology Publishing Corporation.

OPINION



PAUL MOCK

Ivory towers offer golden opportunities

Universities have been increasingly looking to industry for support as government research funding has shrunk in recent years, and Gramm-Rudman-Hollings may result in even deeper cutbacks. A few farsighted companies, such as IBM, Hewlett-Packard, Intel, and Rockwell, have responded. But much of industry remains uninvolved.

For many companies, short-term goals take precedence over anything as nebulous as a research project at a university. How can the benefits be quantified in dollars and cents? Often they can't, just as it's hard to pin a monetary value on making an executive more effective by providing powerful analysis and report-generation tools.

Yet companies that have forged links to universities know they've benefited over the long term. The payoff may be in insights that allow a product to be marketed earlier, tailored more closely to emerging market needs, or manufactured at less cost. Mixing market-wise technical people from industry with bright innovators at universities can create synergies. And companies find it easier to recruit top technical talent.

Opportunities for establishing industry–university links are increasing. For example, the National Science Foundation's sponsorship of academic centers for engineering research is contingent on the universities gaining industry support to complement government funding. Half a dozen such centers were founded last year, and five more were recently announced (see "New engineering centers created," p. 6). NSF promises to expand this program. Several universities have set up microelectronics centers with links to industry, and some states, such as Massachusetts and Utah, are funding "centers of excellence" programs that help get university research results out into the marketplace.

Even though the ivory tower syndrome has moderated, and universities are seeking corporate funding, a company still can't expect to get its next product line designed by grad students. A joint project should instead provide a chance to investigate innovative concepts or tackle generic problem areas—in automating production, for example.

There are other important ways in which companies might forge links. Donating up-to-date equipment is one way, but it's also important to help with operating costs for sophisticated systems. Providing financial assistance for promising students may pay off too. To work out creative programs, corporate managers should go beyond the usual administrative contacts and visit the labs to explore possibilities with hands-on researchers.

Any technology company that expects to be around for a while should be investigating such academic alliances. It's smart business.

Robert Haavind

highTechnology

Editor
Robert C. Haavind

Executive Editor, Steven J. Marcus

Senior Editors, Jeffrey Bairstow, Herb Brody, Dwight B. Davis, H. Garrett DeYoung, Peter Gwynne, Jeffrey Zygmont

Senior Business Editors, Sarah Glazer, Dennis Livingston

Microcomputer Editor, Cary Lu

Copy Editor, David Brittan

Production Editor, Margaret Woisard

Editorial Researcher, Cindy Rainey

Editorial Production Manager, Susan McCabe

Administrative Assistant, Helen Wheeler

Contributors, Ellen Alperstein, Nicholas Basta, Diana ben-Arron, John S. Berestka, Mark Boyer, H. Paris Burstyn, Charles Connell, Rick Cook, Gerard H. Fairtlough, Kevin Finneran, Don Fuller, Gordon Graff, Robert Poe, Salvatore Salamone, Elizabeth Willson

Art Director, Anne C. McAuliffe
Assistant Art Director, Abby Zimberg
Illustrator, Mark E. Alsop
Photo Researcher, Sharon Hopwood

Publisher/Vice-President
Thomas H. King

Circulation Director, David S. Greenough
Circulation Promotion Manager, Mark H. Hollister

Manufacturing Director, Janet A. Kelly

Production Manager, Rebecca Stewart

Director of International Editions, Candace Harris

Public Relations Director, Sherwood Ross

Marketing Services Director, Mark C. Anderson
Sales & Marketing Operations Mgr., Debi Smith
Advertising Promotion Manager, Kim L. Fleischauer

Creative Director, Paul M. Schaffrath

Classified Advertising Manager, Linda Conti

Sales Offices

Boston
W. Robert Boris & Assoc.
P. O. Box 86
Hingham, MA 02043
(617) 749–2196

Jacksonville
J. M. Cerbone & Assoc
504 N. Dixie Freeway
New Smyrna Beach, FL 32069
(904) 427–0356

Chicago, St. Louis
Minneapolis
T. F. Marketing Assoc.
1496 County Farm Ct.
Wheaton, Illinois 60187
Tom Fitzpatrick
(312) 653–1611
Nancy Brown (312) 281-3403

New York
Desmond Abicair
Mark Anderson
Joe Griggs, Arthur Santucci
342 Madison Ave., Suite 1224
New York, NY 10173–0049
(212) 687–6715

Dallas, Denver
Marcus A. Loy and Assoc., Inc.
300 N Central Expy.,
Suite 316
Richardson, TX 75081
(214) 680–0684

Los Angeles
Carroll Walters
1642 Westwood Blvd., Suite 202
Los Angeles, CA 90024
(213) 474–3332

Detroit
Donald L. Rowe & Assoc
2685 Lapeer Road, Suite 207
Pontiac, MI 48057
(313) 373–3950

San Francisco
Forsiak & Assoc., Inc.
P.O. Box 2649
San Anselmo, CA 94960
(415) 461-8366

International Sales Offices

Asia/Pacific
China Consultants Int'l., Ltd.
Tom Gorman
Suite 905, Guardian House
32, Oi Kwan Road
Happy Valley, Hong Kong
(852) 5–833–2181
Telex: 75368-AMR HK HX

Canada
Victor Brown & Assoc., Ltd.
15 Zorra St.
Toronto, Ontario
M8Z 4Z6, Canada
(416) 259–9631
Telex: 06–984747

Aspect Magazine
Mr. Tushiaki Sato
c/o ASCII Corporation
Sumitomo Minato Aoyama
Building 5–11–5
Minami Aoyama Minato-Ku
(81) 3–486–7111
Telex: 242687-ASCIIJ

Europe
Julespage, Ltd.
80 Ebury St.
London SW1W9QD England
(01) 703–6207

Korean Int'l. Adv. Svcs., Ltd.
C.P.O. Box 9109
Seoul 100, Korea
Mr. Jeh-Nam Song
(82) 2–779–1538/9

Caribbean, Central America
Furey & Associates
222 East 46th St., Suite 403
New York, NY 10017
(212) 355–7034

Published monthly by ***High Technology Publishing Corp.***, 38 Commercial Wharf, Boston, MA 02110.

Chairman, Bernard A Goldhirsh; ***Senior Vice-President,*** Gene Simpson; ***Vice-President,*** William C. Taylor; ***Treasurer,*** John W Carlson; ***Controller,*** John J. Reardon

SUBSCRIBE NOW AND SAVE

☐ 1 year (12 issues) of highTechnology for just $21.
☐ 3 years (36 issues) of highTechnology for just $42.

NAME TITLE
ADDRESS APT #
CITY STATE ZIP

Subscriptions to Canada, $26; all other countries, $45 (air mail delivery)
Please allow 4-6 weeks for delivery.

4ANN8

☐ Payment is enclosed ☐ Please bill me later

SUBSCRIBE NOW AND SAVE

☐ 1 year (12 issues) of highTechnology for just $21.
☐ 3 years (36 issues) of highTechnology for just $42.

NAME TITLE
ADDRESS APT #
CITY STATE ZIP

Subscriptions to Canada, $26; all other countries, $45 (air mail delivery).
Please allow 4-6 weeks for delivery.

4ANN8

☐ Payment is enclosed ☐ Please bill me later

t of the trees a long time
rowing rocks at each
ing it. What a colossal

adviser

your excellent editorial
nology adviser for the
6, p. 4).
ight on the head when
e U.S. is slipping badly
rld marketplace. The
g a technology adviser
taff is the best solution

someone in the White
to follow through with
delay will be detrimen-
ffering economy.

record

markets

your excellent article
lies: promises fulfilled"

o clarify my statement
look that sales of anti-
ively tagged antibody
aged heart tissue] are
million in Europe by
.S. market should sur-
mid-1990s. Those fig-
Centocor's sales to ven-
rs' sales to end users.

:
g

NASA

NASA's QSRA. The engine's specially designed housings and location over the wing significantly decrease noise.

The tax form shown on the March 1986 cover was generated by the Interlace program from Singular Software, not Softview's MacInTax.

The doppler radar pictured in "Tomorrow's weather: new accuracy in forecasting" (April 1986, p. 27) belongs to the National Center for Atmospheric Research, not the National Oceanic and Atmospheric Administration.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

For many co
anything as ne
can the benefit
can't, just as it
ecutive more e
generation tool
Yet compani
they've benefit
sights that allo
closely to emer
Mixing market
innovators at u
find it easier to
Opportunitie
creasing. For e
sorship of acad
gent on the un
government fu
last year, and
gineering cent
program. Sever
centers with li
sachusetts and
grams that hel
marketplace.
Even though
universities ar
expect to get it
joint project sh
vative concepts
production, for
There are ot
forge links. Do
also important
tems. Providin
pay off too. To
should go beyond the usual administrative contacts and visit the labs to explore possibilities with hands-on researchers.

Any technology company that expects to be around for a while should be investigating such academic alliances. It's smart business.

Robert Haavind

Robert Haavind

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 68 BOULDER, CO

POSTAGE WILL BE PAID BY ADDRESSEE

highTechnology
P.O. Box 2808
Boulder, Colorado 80321-0001

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 68 BOULDER, CO

POSTAGE WILL BE PAID BY ADDRESSEE

highTechnology
P.O. Box 2808
Boulder, Colorado 80321-0001

Tom Gorman
Suite 905, Guardian House
32, Oi Kwan Road
Happy Valley, Hong Kong
(852) 5–833–2181
Telex: 75368-AMR HK HX

15 Zorra St
Toronto, Ontario
M8Z 4Z6, Canada
(416) 259–9631
Telex: 06–984747

Aspect Magazine
Mr. Tushiaki Sato
c/o ASCII Corporation
Sumitomo Minato Aoyama
Building 5–11–5
Minami Aoyama Minato-Ku
(81) 3–486–7111
Telex: 242687·ASCIIJ

Europe
Julespage, Ltd.
80 Ebury St.
London SW1W9QD England
(01) 703–6207

Korêan Int'l. Adv. Svcs., Ltd.
C.P.O. Box 9109
Seoul 100, Korea
Mr. Jeh-Nam Song
(82) 2–779–1538/9

Caribbean, Central America
Furey & Associates
222 East 46th St., Suite 403
New York, NY 10017
(212) 355-7034

Published monthly by ***High Technology Publishing Corp.***, 38 Commercial Wharf, Boston, MA 02110.

Chairman, Bernard A. Goldhirsh; ***Senior Vice-President,*** Gene Simpson; ***Vice-President,*** William C. Taylor; ***Treasurer,*** John W. Carlson; ***Controller,*** John J. Reardon

PAUL MOCK

LETTERS

Lessons in military spending

As a former design officer in the Navy's old Bureau of Aeronautics, I found your opinion "Correcting the mess in military procurement" (March 1986, p. 4) quite interesting. It's remarkable that no one has asked the people who controlled military expenditures during the Depression how it was done.

During that era I coordinated experimental design studies for new military aircraft, supervised production contracts, and monitored production quality. One company was used to build our production models, and there was exceptional cooperation between design and production engineering. We had penalty clauses in our contracts for such things as unauthorized expenditures—which our factory inspectors checked carefully. We had complete control.

Furthermore, a greedy Congress did not try to tell us what to buy from its contributors. Procurement was very straightforward and honest.

Rear Admiral M. K. Fleming, Jr.
U.S. Navy (retired)
San Diego, Cal.

I was delighted to read your excellent commentary on military procurement. I think the mess is primarily due to the military's parochialism.

Centralization has been discussed for years, but has not made serious inroads. Gramm-Rudman-Hollings is not the real answer; however, it might force another look.

George Wingo
Huber Heights, Ohio

Quiet flight

"Japanese design jets for the short haul" (April 1986, p. 68) gave the impression that the Japanese were the pioneers of the QSTOL plane. You mentioned that the Japanese plane took its maiden test flight last October. However, more than one year earlier at the annual air show held by Moffet Air Field U.S. Naval Air Base (Mountain View, Cal.), NASA's QSRA (Quiet short takeoff and landing research aircraft) displayed its low-speed takeoff and landing ability. The huge plane slowly rising and spiraling in a small radius in the sky was an incredible sight.

Gifford Wooding
Mountain View, Cal.

Tanks for the memories

I read with great interest your article "Why Ivan can't compute" (Feb. 1986, p. 42). I recently returned from a trip to the Soviet Union, where I had the opportunity to visit a school that included both primary and secondary grades. Not only were there no computers or calculators, but the youngest class (six-year-olds) was spending its time shaping clay into miniature army tanks!

Debbi Honorof
Deloitte Haskins & Sells
New York, N.Y.

If you liked acid rain . . .

Your article "Stopping missiles with a *wham*, not a *zap*" (March 1986, p. 62) is enough to make strong men weep. Can't we do any better than this? The amount of sheer ingenuity and devotion going into such futile enterprises is mind-boggling.

Would these whiz kids please tell me what will become of the plutonium that will be released when all those Soviet nasties are shot out of the sky? With midcourse or early reentry-phase intercept, the disintegrating warhead would release masses of plutonium that would remain radioactive despite its meteorlike burning. It seems like a very efficient way of spreading this toxic substance to the globe's entire population.

We came down out of the trees a long time ago and started throwing rocks at each other. We're still doing it. What a colossal waste of talent.

Colin Park
Edmonton, Alberta

NASA

NASA's QSRA. The engine's specially designed housings and location over the wing significantly decrease noise.

On hold: presidential technology adviser

Congratulations on your excellent editorial "Help wanted: technology adviser for the President" (Jan. 1986, p. 4).

You hit the nail right on the head when you stressed that the U.S. is slipping badly in terms of the world marketplace. The suggestion of putting a technology adviser on the presidential staff is the best solution I have encountered.

I just hope that someone in the White House has the sense to follow through with the proposition. Any delay will be detrimental to our already suffering economy.

Craig D. Howland
Guilford, Conn.

Setting the record straight on monoclonal markets

I commend you on your excellent article "Monoclonal antibodies: promises fulfilled" (Feb. 1986, p. 32).

However, I want to clarify my statement in the Business Outlook that sales of antimyosin [a radioactively tagged antibody that identifies damaged heart tissue] are projected to be \$25 million in Europe by 1990 and that the U.S. market should surpass this level by the mid-1990s. Those figures represent only Centocor's sales to vendors, not these vendors' sales to end users.

Solange Israel-Mintz
Director of Marketing
Centocor
Malvern, Pa.

CORRECTIONS:

The tax form shown on the March 1986 cover was generated by the Interlace program from Singular Software, not Softview's MacInTax.

The doppler radar pictured in "Tomorrow's weather: new accuracy in forecasting" (April 1986, p. 27) belongs to the National Center for Atmospheric Research, not the National Oceanic and Atmospheric Administration.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

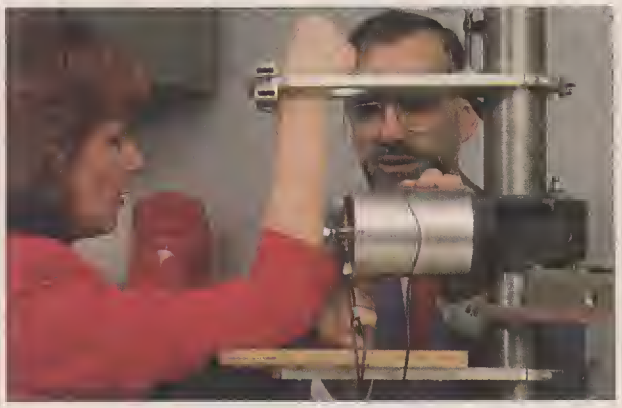
UPDATE

New engineering centers created

In March the National Science Foundation announced the creation of five new Engineering Research Centers (ERCs), raising the total number to eleven. All are based at universities and do multidisciplinary research aimed at solving industrial problems and giving engineering students experience in industrial settings (HIGH TECHNOLOGY, Oct. 1985, p. 48).

The Advanced Combustion ERC at Brigham Young (Provo, Ut.) and the Univ. of Utah (Salt Lake City) will focus at first on the uses and environmental problems of low-cost fossil fuels such as western coal and heavy fuel oil. Carnegie-Mellon's Engineering Design ERC (Pittsburgh) will develop technologies for improving the quality of manufactured goods, while reducing costs and design time. The ERC for Compound Semiconductor Microelectronics at the Univ. of Illinois (Urbana) will work on the use of gallium arsenide chips to relieve interconnection bottlenecks and improve efficiency in high-speed digital systems. The Advanced Technology for Large Structural Systems ERC at Lehigh (Bethlehem, Pa.) will develop design concepts and computer-based tools for industries such as construction, steel, and transportation. Ohio State's Net Shape Manufacturing ERC (Columbus) will study ways of extruding, forging, and casting parts in near-final shape.

The federal government will provide $10–15 million over the next five years to each of the centers, which will also seek industry support. After that, the centers will have to rely on private or state sources. The six centers created in 1985—ranging in focus from telecommunications to biotech—added a total of $13 million in industry funds to the initial $10 million from the government. President Reagan is requesting $35 million in ERC funding for 1987, which would allow for the creation of four more centers.



Stanford's Charles Steele demonstrates his bone-strength analyzer.

Gauging bone strength with vibrations

A device intended for monitoring loss of bone mass in astronauts (caused by long sojourns in the microgravity of space) could also be used on earthbound patients with broken bones, joint implants, or bone loss from osteoporosis and other diseases. The tool, which measures bones' resistance to vibrations, is said to reveal more about bone stiffness than x-rays do. It could therefore allow physicians to prescribe treatment that is better suited to the limits of the damaged bone.

Conceived by Donald Young, a NASA physiologist, and developed by Charles Steele, professor of applied mechanics at Stanford's department of mechanical engineering, the bone analyzer consists largely of a vibrating probe that is pressed against a limb. Two transducers in the probe—one to measure acceleration, one to measure force—send return signals to a computer, which can then calculate the bone's mass and hence its stiffness. Each measurement takes less than a minute.

There are still problems to be overcome, however. "With overweight or very muscular persons, we have trouble getting a good signal from the bone," says Steele. Many companies are interested in manufacturing and marketing the tool, he says, but he wants to wait until it is more reliable.

A better way to make paper

An innovative papermaking process could dramatically boost production rates while reducing energy and materials costs. And unlike conventional technology (which is based on sulfur-containing chemicals), the new enclosed process, called ester pulping, is expected to pose little or no environmental hazard.

Most woods used in papermaking consist of up to 75% chemically recoverable fiber, bound into a tight matrix by a chemical "glue" called lignin. Normally, only about two-thirds of this fiber is released as the chips are cooked in a pulping liquor; the rest remains bound to the lignin. But in ester pulping, an aqueous mixture of acetic acid and ethyl acetate breaks down the lignin more completely, extracting about 93% of the fiber. Moreover, the process takes about 20 minutes at 160° C, versus 2½ hours at 170° C for conventional methods.

Cutaway view of TRW's power steering assembly (right) reveals the dc motor that replaces bulky hydraulic components of a conventional system (below).

Another advantage of ester pulping—which was developed at Biodyne Chemicals, a consulting firm in Neenah, Wis.—is that the process chemicals can be produced at the mill: Fresh acetic acid is automatically generated as a pulping byproduct, and the sugars in the wood can be fermented to form ethyl alcohol, which is then converted to ethyl acetate. What's more, high-quality lignin can be recovered and used in making plywood or particle board.

Biodyne sources note that they're still trying to figure out just how the chemicals act on lignin. Meanwhile, the company expects to have its Neenah pilot plant running by year's end. The process will probably be offered for licensing; already, Biodyne has received inquiries from papermakers in Japan and Finland.

Power steering on demand

A new electric rack-and-pinion power steering assembly for automobiles is said to be lighter, easier to install, and less power-hungry than hydraulic power steering. The Powertronic system from TRW's Steering and Suspension Div. (Sterling Heights, Mich.) has a built-in microprocessor that varies the amount of steering assist, providing maximum aid at low speeds, when it is most needed. What's more, the unit activates only on demand—unlike conventional systems, in which a hydraulic pump constantly scavenges power from the engine. The result, says TRW, is a fuel saving of about 1½ miles per gallon.

The steering assist given by Powertronic comes from a conventional dc motor with a hollow armature shaft that surrounds the rack of the steering mechanism. A set of gears converts the rotary motion of the armature into linear movement of the rack. Sensors in the pinion housing measure the rotation and torque of the steering wheel, and a microprocessor varies the amount of current to the dc motor accordingly.

Powertronic weighs an average of 7½ pounds less than conventional systems, and comes as a complete subassembly that can be installed in one piece. TRW, which says it has agreements with six automobile manufacturers, plans to produce 30,000 Powertronic units for 1988-model cars.

Encoding allows low-cost data distribution

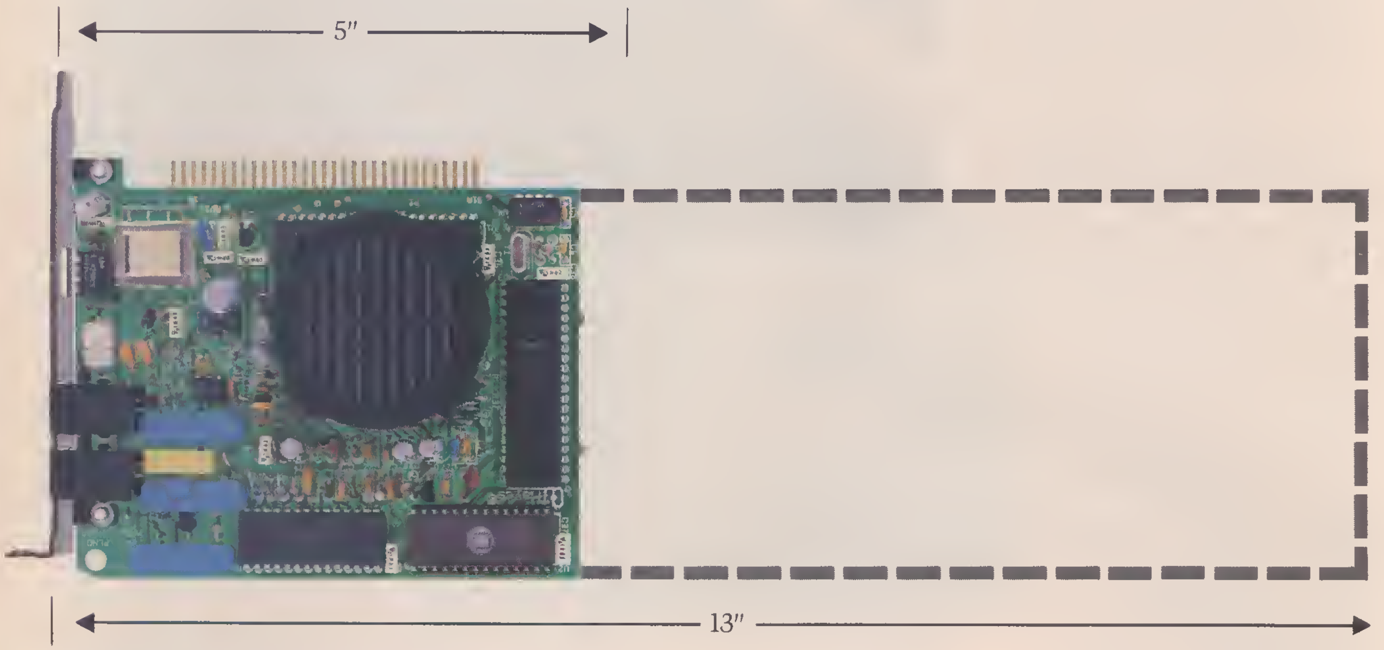
A radio transmission technique originally developed for use by the military to avoid jamming is thriving as a means of providing low-cost data distribution networks for news, stock reports, and other information. The technique, known as spread spectrum, allows satellite data to be received by small antennas—two feet in diameter instead of six feet or more—greatly reducing the cost of a system.

Because C-band communications satellites (the most commonly used) are packed close together, homing in on a particular satellite normally requires a large antenna. To get around this problem, radio transmitters used in data networks set up by Equatorial Communications (Mountain View, Cal.) are equipped with encoders that spread digital data in a discrete pattern over the full 5-MHz bandwidth of a satellite transponder. The result is a broad stream of weak pulses, instead of the usual narrow stream of strong pulses.

The antenna on the ground receives interference from other satellites, but it is able to separate out the desired signal by "despreading" it with the same code originally used to spread it. That way, unwanted signals simply appear as noise. By applying different codes, as many as 80 users at a time can send messages over the same satellite transponder.

Each bit of data requires several bits to encode it, so transmission is relatively slow. Nevertheless, Equatorial has established data distribution networks for the New York and American stock exchanges, Dow Jones, Associated Press, the National Weather Service, and other organizations—networks that serve some 30,000 receivers. Last year the company began marketing an interactive system that transmits as well as receives, intended mainly for corporate communications.

The largest selling 1200 bps modem just got smaller.



©1986 Hayes Microcomputer Products, Inc.

The new Hayes Smartmodem 1200B™

Now you can get a lot more out of your PC, by putting a little more in. Our new Hayes Smartmodem 1200B includes the same quality and advanced features that have made it the leading 1200 bps modem. Now, advances in Hayes technology allow us to make it available in a size that fits either full slots or a "single" half slot.

That's important news if you have an IBM,® AT&T,® Compaq,® Tandy® or other compatible computer with half slots. It means with a Smartmodem 1200B, you can free up one of your full slots for an additional function, such as color graphics, more memory or networking. Or, if you prefer, you can continue to use the new Smartmodem 1200B in one of the full slots. Hayes makes it easy and versatile to fit your needs.

There are many good reasons for choosing Hayes. Our new space-saving Smartmodem 1200B is one of them. Hayes Smartcom II,® the industry's best selling communications software, is another.

Smartcom II for the IBM and compatibles makes short work of communicating, while allowing you to take full advantage of the sophisticated capabilities of your Smartmodem 1200B. Together, they create a powerful, yet easy-to-use, communications system for your PC. They're made for each other, and customized for IBM PC's.

The best reasons of all for choosing Hayes are the "built-in" benefits. Advanced technology. Unsurpassed reliability. And a customer service organization that's second to none.

So, when you see your authorized Hayes dealer ask for the largest selling 1200 bps modem. Smartmodem 1200B. And remember. Now it's smaller, too. Hayes Microcomputer Products, Inc. P.O. Box 105203, Atlanta, GA30348. (404) 441-1617.

Hayes®

Say yes to the future

Circle No. 26 on Reader Service Card.

Consider the cell

Gerard H. Fairtlough
Chief Executive Officer, Celltech Limited

Today's business environment is dramatically different from that of our forebears. Whereas the high-performance company of the past usually resembled a massive machine, it now tends to be relatively small. Once controlled almost exclusively by one person at the top, today it is often guided by several individuals or groups who share responsibilities as well as privileges. And while the movements of older companies were often restricted by tradition and corporate ritual, their young 1980s counterparts respond to changing conditions quickly and gracefully.

To the biologist, such comparisons may sound familiar; they suggest that while the innovative company once resembled an unthinking automaton, it now bears a striking similarity to a living cell.

Consider just a few of the features that characterize all cells:

- They are largely self-contained and are densely organized for intensive internal communication.
- At the same time, they constantly exchange products and services, and "talk" with other cells in a complex networking system.
- Despite their great diversity, all cells live by rigid rules of competition and cooperation set by the larger cellular framework; within this framework, an unruly cell either destroys its surroundings or is itself destroyed by other cells.
- Cells are continually evolving. New molecules emerge, new reactions are attempted, new relationships are assessed and either adopted or discarded. In such trial and error, however, only those relationships that promote the well-being of both the cell and the host organism are permanently integrated into the cellular life.

Celltech is a biotechnology company headquartered near London.

If we accept the premise that innovative companies resemble living cells, we may also surmise that these two forms of life share many of the same needs and reactions to external stimuli. What, then, are the commercial implications of this similarity?

One is related to physical structure: Look carefully at many young, dynamic companies, and you will be impressed by their compactness. As in the cell, little or no space is wasted. Individual members often seem to be uncomfortably close to one another; personal interactions are not only common within such a setting, they are unavoidable (which is the main point of such crowding, of course). While at odds with the popular notion of openness and grand-scale aesthetics, this density is critically important to the cell's internal communications—and to the company's.

The innovative company bears a striking similarity to a living cell.

Newcomers to biology are often dazzled by the seemingly infinite variety of cells. A blood cell looks nothing at all like a cardiac cell, and even less like a nerve cell. Yet each one is designed to function according to ancient, unbreakable rules that serve the larger system. The nonfunctioning cell, or the cell that suddenly grows chaotically or without limits, is destroyed lest it become a hazard to its neighbors.

The idea of operating creatively within a recognized system implies an obligation by every company to conform to certain behavioral norms. At the very least, this means high standards of safety for the worker and the customer, an unimpeachable code of ethics that governs corporate policy and marketing strategies, and professional responsibilities to clients, affiliates, and competitors. Moreover, these frameworks are not usually imposed from above—when they are, they often inhibit the creative process—but are generated by professionals who understand and support them.

Another implication of the company–cell comparison relates to external communications. Just as no cell exists alone for very long, so no company exists in a vacuum; both need regular and extensive contacts with the outside world to survive. Every cell constantly communicates with other cells, exchanging energy, proteins, gases, neurotransmitters, and electrical signals. Companies exchange not only goods and services, but also the intangible commodity called knowledge.

Finally, note the evolutionary nature of the living cell—the continuous experimentation and evaluation by which it maintains itself against adversity. The cell that fails in this effort is doomed to extinction and is replaced by new, more vigorous cells. Likewise, companies must recognize the need to evolve—to transform in order to meet new conditions and demands.

Such corporate flexibility carries a price, of course. Some managers may be distressed to find that sacrifices will be required. There may be long periods during which they have to forgo their impressive new buildings, spacious offices, and luxurious executive lunchrooms, along with the tidy organizational structures that are often tailored more to the needs of management than to those of the company as a whole. But the sacrifices are well worth making. Like the living cell, the innovative company can achieve some truly astonishing results. □

BUSINESS STRATEGIES

Convergent Technologies:

SUFFERING EXPANSION PAINS


RICK BROWNE

Although recent merger plans were thwarted, Convergent will continue to seek growth through acquisitions, says CEO Paul Ely.

After years of making computers to be sold under brand names of companies such as AT&T Information Systems, Burroughs, and NCR, Convergent Technologies (San Jose, Cal.) may be trying to shed its anonymity. But with few ties to independent computer dealers and no direct-sales force of its own, developing the channels to sell under its own name could be painstakingly slow. Although Convergent almost found a shortcut via a proposed merger with 3Com—a rising young maker of computer networking equipment whose products are sold mainly by computer dealers—the merger fell through in late March, leaving Convergent to search for new partners to help broaden its marketing channels.

Seven-year-old Convergent had itself been a fast-growing star during the computer industry boom of the early 1980s. In 1984, however, it sustained a $13.8 million loss after a new portable computer flopped and its main product line—networked systems for up to 64 users—ran into technical problems. Under the direction of a new CEO, Paul Ely (previously head of Hewlett-Packard's computer groups), the company recovered steadily and reasserted itself as a low-cost manufacturer of technically innovative office computers. In 1985, it earned $11.5 million on sales of $395.1 million, over half of which came from large-volume contracts with its two biggest customers: AT&T and Burroughs.

But Convergent's apparent progress toward health was interrupted by its performance in this year's January–March quarter. The company's sales, estimated at $70–80 million, were down so sharply from the previous quarter's $99.6 million total that a stock swap set for the proposed merger with 3Com would have needed restructuring. (3Com's revenues had unexpectedly jumped for the period, throwing the initially proposed terms even more out of kilter.) Unable to negotiate new terms, the prospective partners dissolved the merger. "It was disappointing," says Ely, who attributes his company's drop in revenues mainly to a slowdown in orders from AT&T—which by itself accounted for 40% of Convergent's sales last year.

Sales may continue to fluctuate, contends Don F. Sinsabaugh, managing director of securities brokerage firm Swergold Chefitz & Sinsabaugh (New York), as long as Convergent remains dependent on a few large computer manufacturers. Both AT&T and Burroughs have contractual rights to bring manufacturing in-house, and both certainly have the production capacity to do so. AT&T also deals with numerous other suppliers, ranging from Olivetti to start-up Counterpoint Computers (headed by former Convergent executive Pauline Alker). "These big contracts were good for Convergent's initial growth," says Sinsabaugh, "but not for the long term." John Dean, an analyst for Montgomery Securities (San Francisco), agrees. For stability, he says, the company would be better off with a larger number of medium-size customers and with market channels for reaching small companies that buy computers for their own use.

Convergent does have plans to reach small customers, according to CEO Ely. He maintains that its purchase last year of Baron Data Systems, a vendor of computers for court reporters, was just the first in a series of acquisitions of firms that adapt computers for specialized markets. "The [3Com] merger plans put other acquisitions on hold," he says, "but now we'll be moving ahead." Convergent also plans to continue working with 3Com—although "at arm's length"—to develop and market several products jointly for both the computer dealership channel and for Convergent's large customers. And another merger may even be in the cards, says Ely, although it could take some time to set the wheels in motion.—***Sarah Glazer***

Insituform:

MENDING SEWERS WITHOUT DIGGING

A five-year-old Memphis-based company is cashing in on the crumbling of mile upon mile of pipes in the nation's sewer systems. Insituform of North America, which owns the U.S. patent rights to a technology for relin-

ing sewer pipes with little or no excavation, has seen its revenues jump from $740,000 in 1982 to $8.6 million in 1985. With the need for municipal sewer repairs estimated at $5–10 billion through 1990, there's good reason to believe the company can sustain its rapid growth, says analyst Charles Flynn, VP of research for Morgan Keegan & Co. (Memphis). "In addition to the municipal sewer market," he notes, "there is an industrial sewer market and possibly even a drinking-water-pipe market."

The repair process, developed in England by the Insituform Group, consists of forming a new pipe lining from a fabric tube inserted into the damaged structure—thus the company name (*in situ* is Latin for "in place"). A high-pressure stream of cold water forces the fabric tube—made of polyester felt and coated with a liquid resin that remains pliable until exposed to high temperatures—into the sewer pipe and holds it against the pipe walls. The water then circulates through a portable boiler, which heats it to a temperature that cures the resins, creating an impermeable, corrosion-resistant lining.

Insituform limits its activity to the fabrication of pipe lining; the actual installation work is done by 11 licensees nationwide (which charge an average of $300,000 a mile for eight-inch pipe). So far, two-thirds of the company's revenues have come from sales of resin-impregnated tubes and the rest from an 8% royalty that licensees pay on the total cost of every job. Annual revenues from installations have soared from $5.2 million in 1982—the year installations began—to $34.3 million in 1985, and customers include the cities of Detroit, Baltimore, Fort Wayne (Ind.), and Freeport (N.Y.), the Washington Suburban Sanitary District in Maryland, and Anheuser-Busch (for sewer line repairs in its St. Louis brewery).

After a rocky first year, in which Insituform plunged $806,000 into the red, the company managed to steady itself, financed primarily through public stock offerings. Last year, its profits were $1.2 million. And with many of the nation's post–World War II sewer pipes approaching the end of their service lives (which average 40–50 years), Insituform can expect to be in demand, says Flynn, as the only company currently able to mend pipes without large-scale excavation. The company also expects to have another market to itself—*in situ* repair of drinking-water pipes—if the Environmental Protection Agency approves its process. (Action is expected later this year.) Nonetheless, the company's vice-chairman, Robert Leopold, admits to a "healthy paranoia" about eventual competition, and plans to accelerate both marketing and R&D activities.

The company's greatest obstacle, however, is the inertia of its customer base. "Cities are reluctant to spend money on infrastructure repairs until they have to," says Flynn.

—Elizabeth Willson

Microgravity Research:
GROWING CRYSTALS IN SPACE

NASA's efforts to drum up commercial business for the Space Shuttle and proposed space station had not been going especially well even before the Challenger disaster, but at least one company is so committed to working in space that it plans to locate its entire manufacturing operation there. Microgravity Research Associates (MRA—Coral Gables, Fla.) intends to grow crystals of the advanced semiconductor material gallium arsenide (GaAs) in space, starting in 1988 with a series of experimental production runs aboard the shuttle. In the early 1990s it hopes to establish a permanent orbiting production line, either on NASA's space station or on one of the platforms being proposed by private industry.

What makes growing GaAs crystals in space so attractive is the extreme difficulty of producing uniform crystals on earth from gallium and arsenic atoms suspended in solution. Convection currents created by gravity cause the heavier atoms to sink, making the crystalline structure uneven and the material's electrical properties inconsistent. Only 10–20% of today's commercially produced GaAs is uniform enough to make into the wafers used to manufacture microchips, says Russell Ramsland, MRA's founder and chairman. In contrast, all the material grown in the weightlessness of space should theoretically be defect-free, he contends. The prospect of charging premium prices for these high-quality crystals (three-inch-diameter earth-grown crystals are currently priced at $250,000 per kilogram) begins to make an orbiting production line seem economically feasible. MRA estimates that each of the seven planned experimental runs—housed aboard the shuttle for free, under a joint-endeavor agreement with NASA—will produce 25–30 kg of three-inch-diameter crystals.

Before the flights can take place, however, the five-year-old company must overcome several practical obstacles. Its unconventional production process, for which it owns exclusive patent rights, is still being refined at MIT, where it was developed. And MRA's $1.5 million in financing from a limited R&D partnership will have to be supplemented with additional capital, reports company president Richard Randolph. MRA may try to find a market for the high-quality half-inch-diameter crystals being produced in the MIT tests, he says, even though they are too small to make into wafers.

What could ground the entire project, though, is the possibility that no substantial market will materialize for space-grown GaAs crystals. Although the U.S. alone consumed more than $300 million worth of GaAs in 1985, according to research firm Strategic Inc. (Cupertino, Cal.), most of this was used for the kind of small-scale analog devices that don't require defect-free material. By the time demand for digital-quality material becomes sufficiently great, improvements in terrestrial production techniques may have made it widely available at down-to-earth prices.

Finally, MRA may have to face serious competition in the race to capture whatever market eventually emerges for space-grown crystals. Gary Krier, director of the commercial devices division in NASA's Office of Commercial Programs, reports that several companies are already negotiating to do crystal research on NASA's proposed space station. ***—Diana ben-Aaron***

TRANSFORMING THE FAMILY CAR

Today's motorists insist on performance. Automakers are responding with small but powerful engines and advanced chassis systems such as four-wheel steering and adjustable suspension.

LITTLE ENGINES THAT CAN

They were declared terminally ill during the fuel panics of the '70s, but today gasoline-powered automobile engines are in such good health that the auto industry has all but abandoned the alternative power sources that were expected to replace them. Resurrecting the traditional workhorse—the spark-ignited, reciprocating piston engine—are innovations that not only assure economy, but at the same time improve output to deliver the high performance that motorists are demanding.

by Don Fuller

Although modern gasoline engines comply with the basic operating principles of their predecessors, almost every subsystem is being radically reengineered. Sometimes this can be done through modifications to old designs, relieving some of the expense of retooling for whole new engines. General Motors' Chevrolet Division (Warren, Mich.), for example, is still improving its basic V-8 engine, which is over 30 years old, while the highly sophisticated turbocharged V-6 used by the Buick Division (Flint, Mich.) derives from an aluminum V-8 engineered 25 years ago. Yet at the same time, totally new configurations, such as the new family of double overhead camshaft, four-valve-per-cylinder engines being developed

Oldsmobile's Donald Miles (left) and chief engineer Theodore Louckes pose with the Quad-4 engine they helped create.

ROGER HILL

by Toyota Motor (Toyota City, Japan), are also being introduced.

The fundamental change in ignition systems that began when microprocessor control arrived in 1977 is leading to distributorless setups with more precise spark control. And fuel systems—likewise revolutionized by electronically controlled fuel injection earlier in this decade—are entering a new era of refinement as airflow becomes a major concern of engine designers. On the horizon still are new materials, particularly ceramics and plastics, that are expected to propel engine performance past the limits of current technology.

Breathing easier. An internal combustion engine is essentially an air pump: The downward stroke of each piston sucks in a mixture of gasoline and air; and the upward stroke pushes waste gases out of the cylinder after the fuel burns, making room for a fresh charge. Therefore significant improvements result from streamlining the flow of fuel and air into and out of cylinders.

When the demand for small-engine performance took hold early in this decade, turbocharging was the technology of choice. Turbos are air compressors, pressurizing the intake charge to force more air into the combustion chambers. But they carry a price: In addition to requiring cumbersome air passages around the engine, turbos are costly to manufacture. Because they spin at over 100,000 rpm, special materials and high-precision manufacturing are required. For longevity, most modern turbos have water-cooled bearings, another complicating factor.

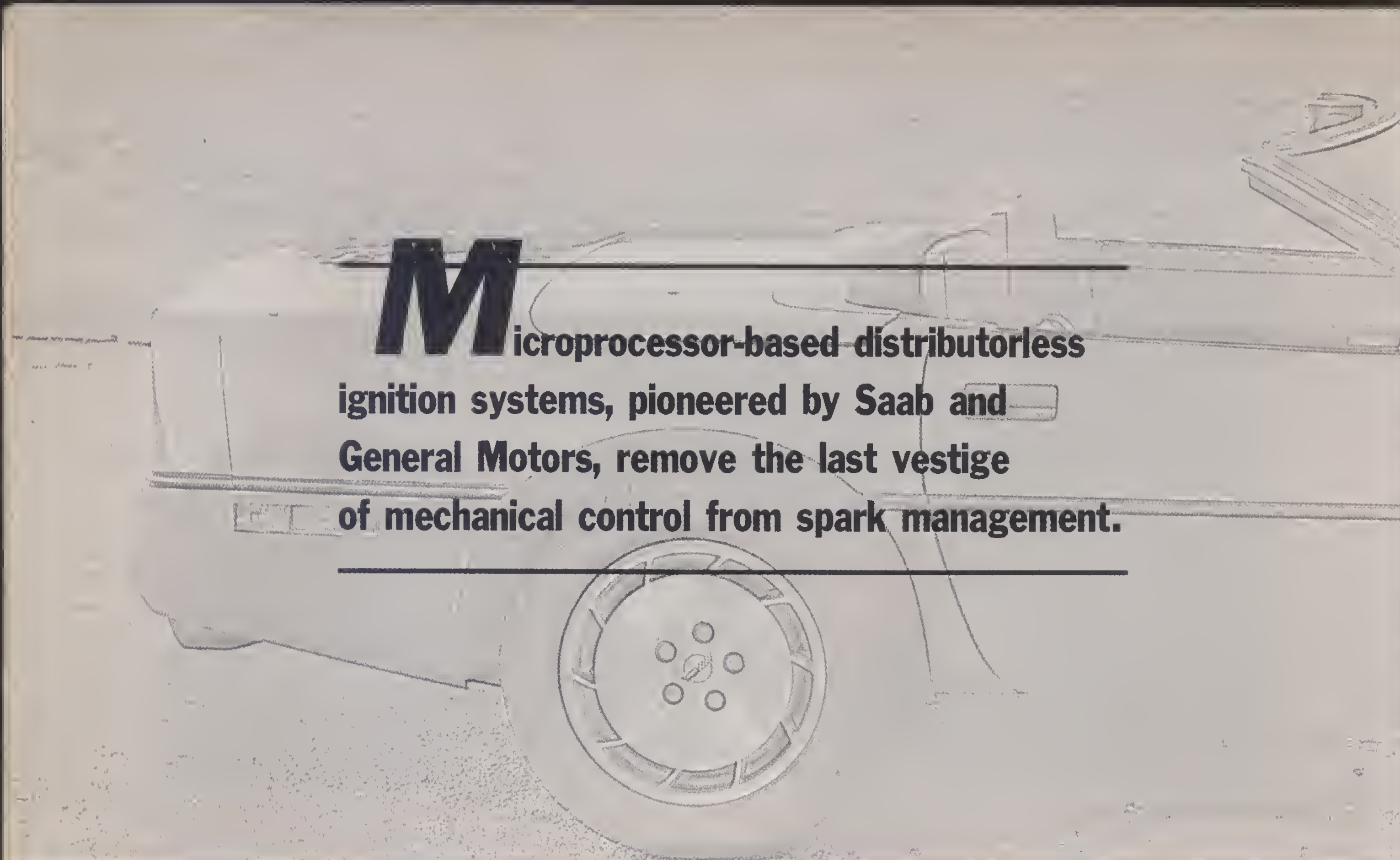
But now, multiple-valve engines are rapidly gaining favor as a way to improve fuel flow. "They have power that won't quit, and they don't have all the complications of a turbocharger," says Donald L. Miles, assistant chief engineer of powertrains for GM's Buick-Oldsmobile-Cadillac Group.

Gasoline and vapor enter and exit an engine's combustion chambers (the area at the top of each cylinder) through valves; conventional engines have one intake and one exhaust valve per cylinder. Since the early days of autos, engineers knew that increasing the number of valves could improve flow and thereby increase both horsepower and efficiency. But the cost of extra valves limited them to racing engines and motorcycles, where the enhanced performance justified the expense.

Now, however, four-valve-per-cylinder layouts (with two valves at the intake and two at the exhaust) are beginning to appear. (Four-cylinder engines that use this configuration are known as 16-valve engines).

Testing their 2.3-liter multivalve engine for model 190 sedans, engineers at Mercedes-Benz (Stuttgart, West Germany) reported in October 1984 that in addition to improving intake and exhaust flow by about 25%, the four-valve layout made it easier to position the spark plug near the center of the combustion chamber. This promotes quicker, more efficient fuel combustion, since the flame spreads from the center. Also, with four small valves instead of two large ones, each valve weighs less. Thus proportionally less energy is lost when opening and closing them, and friction is reduced. "This engine delivers extremely high power while showing good fuel economy, and complies with EEC emissions specifications," reported the Mercedes-Benz engineers to the Society of Automotive Engineers (Warrendale, Pa.).

But multivalves aren't without problems. At low engine speeds, when air intake is lower, the increased inlet area is so big that air enters the cylinder too slowly to promote turbulence—essential for thorough mixing of oxygen and gasoline particles before ignition. Mixing is critical to complete fuel combustion, hence to efficiency. At Saab-Scania (Linköping, Sweden), engineers solved the problem by redesigning air inlet tubes to create uneven airflow—and thus cause turbulence—regardless of engine speed. "If the air enters the cylinder faster on one side than the other, it will spin, stirring up a homogenous fuel–air mixture," explains Gunnar Larsson, Saab technical director. Toyota, the leader in multivalves, with



Microprocessor-based distributorless ignition systems, pioneered by Saab and General Motors, remove the last vestige of mechanical control from spark management.

16-valve engines in its Corolla GT-S, MR2, and Celica GT-S, closes off one of the two intake ports in each cylinder at low speeds, assuring adequate airflow for turbulence. Then, at a predetermined engine speed, the tubes open for more power.

Using a much simpler, though more sophisticated, approach is the new Quad-4 engine, a 2.3-liter, four-cylinder, 16-valve design created by GM's Oldsmobile Division (Lansing, Mich.) and due for production in 1987. The engine harnesses the inherent air-pressure pulses resulting from the opening and closing of the intake valves. Each of the Quad-4's cylinders has its own 16-inch-long inlet pipe drawing fresh air from a common chamber. This inlet system is carefully shaped to form a Helmholz resonator—an air chamber that resonates at a specific frequency. The Quad-4 resonator is tuned so that at low engine speeds the air-pressure peaks coincide with the opening of the intake valves, forcing enough air into the combustion chamber to assure adequate mixing. Such intake tuning also improves the performance of conventional auto engines; it's used on the V-6 for Ford's Taurus and the high-performance V-8 for the Chevrolet Corvette.

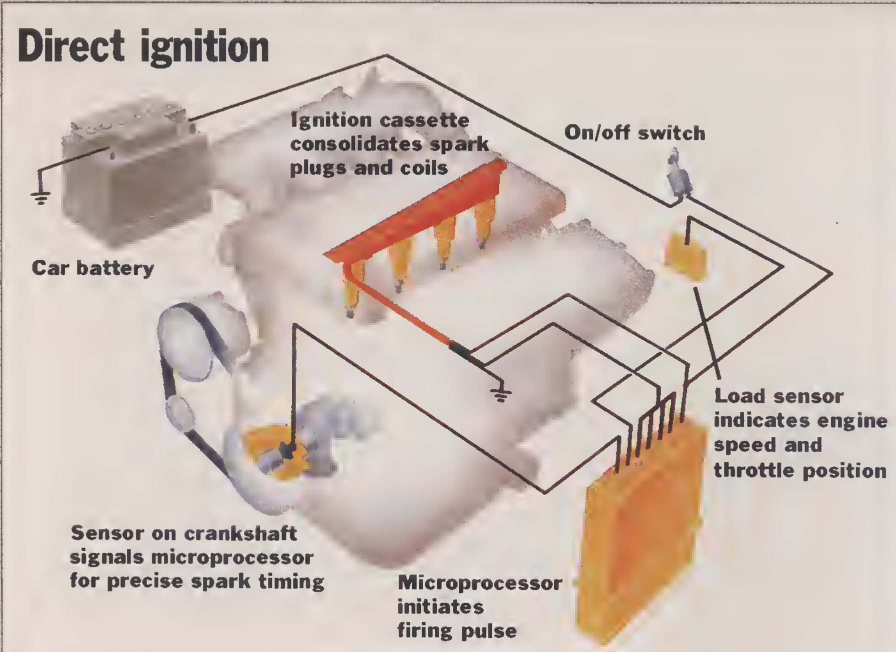
Although current multivalve engines use four valves per cylinder, the benefits multiply with even more valves. In 1985 Yamaha introduced a motorcycle with five valves per cylinder—three intakes and two exhausts. Yamaha engineers say they experimented with as many as seven valves—four intakes, three exhausts—with power and efficiency gains at each step. They finally limited themselves to five because of manufacturing expense. The company's V-6 five-valve-per-cylinder racing engine for Formula 2 cars is reported to develop about 330–350 horsepower. "It is also possible to apply the five-valve system to a standard automotive engine," says Yamaha engineer Hiro Kozu, "but we must study the cost first." Maserati, the Italian manufacturer of exotic sports cars, is preparing a V-6 with six valves per cylinder.

Per Gillbrand, Saab's chief of engine development, says that multivalve technology "will maintain its dominance well into the next century." But turbochargers won't disappear. Despite their complexity, turbochargers are well suited to small engines because they are "on-demand" systems. Increasing engine speed creates more exhaust pressure, which spins the turbine faster, gaining power by upping intake air pressure. Thus, with a turbo, a small engine can still be economical if driven conservatively, but will supply more power on demand (HIGH TECHNOLOGY, May 1983, p. 22).

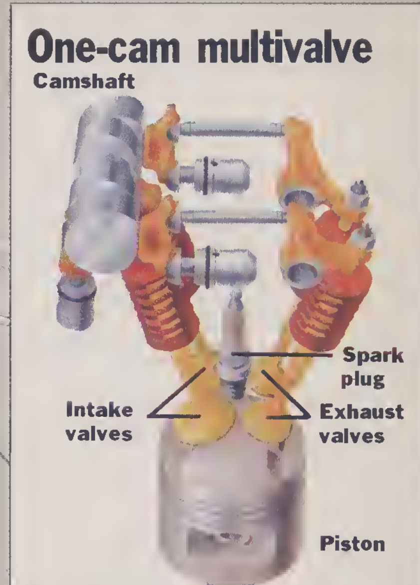
By pressurizing intake air, however, turbochargers increase its temperature. The corresponding drop in air density reduces the oxygen available for combustion. To cool the charge after leaving the turbo, many newer applications incorporate an intercooler—a radiatorlike heat exchanger between turbo and engine. An intercooler adds negligible weight, does not affect fuel economy, and allows designers to increase the engine's fuel compression without risk of detonation (a damaging tendency of overheated fuel to burn erratically in the combustion chamber). With higher compression, more of the fuel's thermal energy is harnessed.

Saab uses an intercooler to drop intake temperature from 250° F to 140°, permitting a compression ratio of 9:1, remarkably high for a turbocharged engine. An intercooler in Mitsubishi's Starion ESI provides a similar temperature reduction. Because of the cooler charge, engineers were able to increase maximum turbo boost pressure from 7.8 psi to 8.7. Horsepower increased from 145 to 170, while torque went up from 185 pound-feet to 220. Similarly, Buick added an intercooler to its turbocharged V-6, increasing horsepower from 200 to 235.

Lighting the fire. At present, engine management computers can coordinate fuel injection and spark timing to optimize both economy and performance. One state-of-the-art engine computer, the Electronic Engine Control-IV (EEC-IV), used in several Ford cars, receives signals from 20



Saab's direct ignition system eliminates mechanical distribution and the cumbersome high-voltage wires of conventional systems. Instead, a microprocessor controls the firing of each spark plug according to engine load and piston position. Saab says this integrated setup eases maintenance and adds reliability. "The system is so stable that the ignition never needs adjustment," says engine development chief Per Gillbrand.



Although most four-valve-per-cylinder engines operate valves with dual overhead camshafts in each cylinder head, Honda's simpler layout for its Acura Legend V-6 uses only one camshaft per cylinder head, reducing weight and producing a narrower engine that fits more easily under the hood.

ILLUSTRATIONS BY MARK E. ALSOP

sensors, monitoring such variables as coolant temperature, exhaust-gas oxygen content, crankshaft position, throttle position, and vehicle speed. It controls 22 functions, regulating the ratio of gasoline to air as well as ignition timing and strength. "We've also introduced adaptive controls," says Ford vice-president of car development Stuart M. Frey. "If your car has a problem starting when it's cold, EEC-IV puts that in its memory, makes a diagnosis, and by about the tenth start has adjusted engine functions to fix the cold-start problem." Throughout the industry, computer engine control is finding its way even into low-priced cars as the cost of electronics declines. By 1990, says Frey, "Ford will be 100% electronic in engine controls."

The next major innovation in computerized engine control will likely be distributorless ignition. On a conventional engine, sparks originate in the coil—a transformer that uses induction to generate thousands of volts from the car's 12-volt electrical system. Engines commonly have one coil, which distributes its sparks in proper sequence through the octopuslike distributor to the spark plug wires. The distributor uses the engine's rotary motion to transfer sparks among its radial nodes. By eliminating the distributor, however, automakers gain the greater precision of electronic control.

Buick pioneered distributorless ignitions in 1984 with its Computer Controlled Coil Ignition, which replaces the six-cylinder engine's single coil with three coils, each wired to two spark plugs. The firing of each coil, controlled by microprocessor, coincides with the proper firing time for one of the coil's two spark plugs. (Both spark plugs actually fire simultaneously, but ignition occurs in only one of the cylinders—the one with the right fuel–air conditions.)

In its Quad-4 engine, Oldsmobile takes the concept a step farther, integrating its two coils and four spark plugs in a single, protective housing on top of the engine. This eliminates the high-voltage connecting wires—a common source of engine problems—so that less voltage is lost during spark transmission and more energy is delivered directly to the spark plugs.

While GM is preparing Quad-4 for production starting in 1987, Saab-Scania is field-testing an alternative approach: a direct ignition system with reduced reliance on inductive ignition coils. Configured similarly to the Quad-4 ignition but with a separate coil for each of the four cylinders, Saab's system generates sparks by first applying the 12-volt current to capacitors near the plugs, which step up voltage to 400 volts. The final 40,000 volts is generated by small, high-powered induction coils fitted directly over each plug. By relying on induction for only a 100-fold voltage increase—instead of more than 2000-fold, as with standard coils—this system generates a higher output faster, says Saab's Gillbrand. Whereas conventional inductive systems need 20 microseconds to build up a 25,000-volt firing charge, he says, Saab's direct ignition is ready with 40,000 volts in 1 microsecond. "We get better fuel economy, higher power, and less sensitivity to variations in fuel quality."

A potential liability of capacitive ignition systems is that the sparks last only a tenth as long as in inductive systems. But Saab's individual coils avoid this problem, since they can be controlled more precisely than slower, mechanically driven distributors, timing the spark to ideal combustion-chamber conditions.

Replacing metal. Still to come are the considerable gains in engine performance and efficiency expected from plastics and ceramics. Because plastic engine components are lighter, they consume less power—a plastic shaft, for instance, takes less energy to rotate than a metal one. What's more, the lighter weights of rotating and reciprocating engine components produce less vibration and noise. The durability of reinforced plastics in automobile engines is being demonstrated by a four-cylinder plastic racing motor built by Polimotor Research (Fairlawn, N.J.). The engine, which has competed in races for several years, is

Instead of just taking the air as it comes, the Corvette's 5.8-liter V-8 has a tuned intake system. The combination of central air chamber and serpentine inlet tubes controls the frequency of the incoming airstream so that a high-pressure pulse arrives at the intake valve when it opens, forcing more air into the combustion chamber.

Chrysler's chief powertrain engineer, William Weertman, shows a Plymouth Laser with balance shafts to make the engine run smoother. Natural imbalances of the car's four-cylinder engine are canceled by calibrated imbalances in a pair of counterweighted shafts that are driven at twice the speed of the engine.

63% plastic by weight, with metal faces on parts exposed to combustion (HIGH TECHNOLOGY, Dec. 1985, p. 67).

In engines as well as other automotive applications, plastic parts generally still cannot be produced as quickly as metal. Therefore major suppliers like Amoco Chemical (Chicago), General Electric (Pittsfield, Mass.), and Mobay Chemical (Pittsburgh) are developing lower-cost molding processes with shorter cycle times. But since most development concentrates on body and structural auto components, the prospect for the near-term use of plastics inside engines is uncertain. "Until a manufacturing process is developed that will reduce costs sharply," says Ford's Frey, "use of graphite-reinforced plastics will be confined to race cars."

The auto industry is more enthusiastic about silicon nitride and aluminum oxide ceramics in engines; they're "the wave of the future," says GM's Miles. As with plastic, however, production technology is a major hurdle.

Ceramics are so hard that they must be machined with costly diamond-coated cutters. The joint venture Norton/TRW Ceramics (Northboro, Mass.) is therefore developing "net-shape forming," which produces a ready-to-use ceramic component right out of the mold, and thus eliminates or significantly reduces machining. Research is also under way to develop techniques for mass-producing ceramic parts without "voids"—blemishes that lead to stress fractures in the brittle material. "Our goal is to find ways to manufacture parts with extremely good consistency," says Craig Marks, vice-president for science and technology at the Worldwide Automotive Sector of TRW (Cleveland).

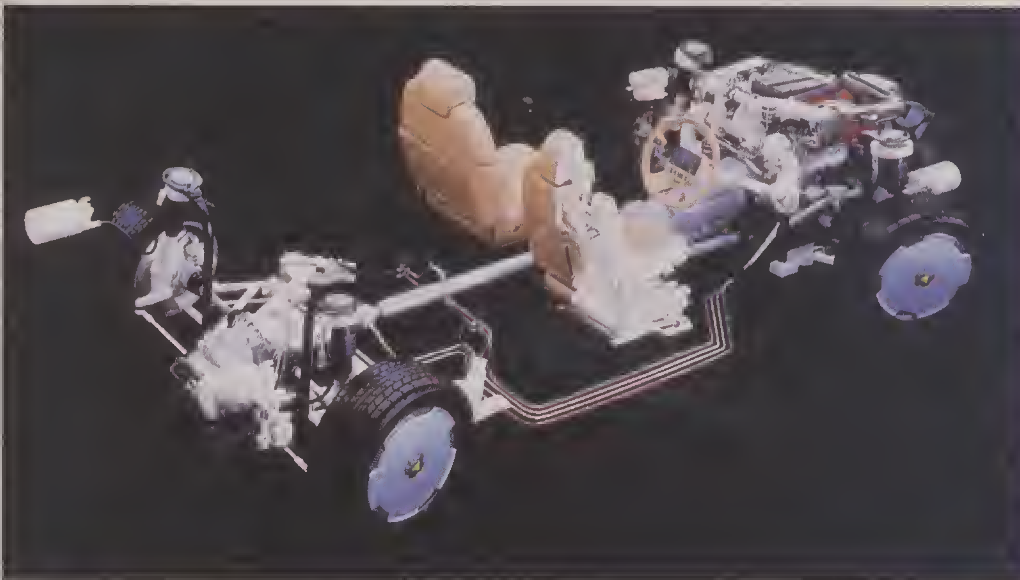
Besides sharing the light weight and low frictional properties of plastic, ceramic components are extremely durable, reducing engine wear and extending longevity. Also, their dimensional stability over the wide range of engine temperatures keeps them within a close fit, improving engine efficiency.

Unlike metal, ceramic transfers almost no heat. Researchers are trying to harness this insulating property to develop an adiabatic engine, a motor that uses full fuel energy with no losses due to heat transfer. Current auto engines sacrifice about 75% of the fuel's energy as heat is conducted through metal parts or lost in exhaust gas. By preventing heat loss, ceramic-wrapped cumbustion chambers would render the engine's cooling system obsolete, greatly simplifying engine design, manufacture, and operation, as well as permitting body designers to slope a car's front end for greater aerodynamic efficiency.

But adiabatic principles are incompatible with spark-ignited gasoline engines, since the higher combustion temperatures promote detonation. Adiabatic designs are therefore based on diesels, which are even more efficient at significantly higher combustion temperatures. Isuzu (Tokyo) is developing a turbocharged adiabatic with a reported 30% improvement in fuel economy. Production is set for 1990. Also researching adiabatics are Ford, Volkswagen (Wolfsburg, West Germany), Toyota, Mitsubishi (Tokyo), GM's European operation Adam Opel, and the heavy-duty diesel maker Cummins Engine (Columbus, Ind.).

While adiabatics won't be ready for a few more years, the direct substitution of ceramic for metal engine parts is more immediate. In Japan, Nissan (Tokyo) already uses an all-ceramic turbocharger rotor on its 300 ZX sports car, considerably improving turbo performance. TRW's Marks says major ceramic engine parts may appear by 1990. Likely candidates are parts subject to heat or wear, such as valve-train and piston components. In areas where steel may still be necessary for its high fracture strength—like the connecting rods joining the pistons with the crank shaft—microscopic ceramic "whiskers" and particles can be alloyed with metal. According to Richard Alliegro, a Norton vice-president and the president of Norton/TRW Ceramics, a mix of just 10–20% ceramic makes a part harder, lighter, and more heat-tolerant.

Although innovations continue to improve the efficiency—and chances for continued predominance—of spark-



Nissan designed the chassis of its Cue-x prototype car—with four-wheel steering, all-wheel drive, and adjustable suspension—"to respond to its driver's inputs faithfully, without imposing any demands of special skill."

ignited gasoline engines, alternative automotive power sources should not be counted out altogether. In *Prospects for Future Fuel Economy Innovation in Light Vehicles* (now in final draft), the Federation of American Scientists notes that, even with the coming advances, gasoline engines are inherently less efficient than many alternatives. What's more, oil supply prospects point to the continued need for fuel economy, despite recent price declines.

Fuel economy remains a major goal of all engine development programs. But small engines must also have more power, says Oldsmobile's Miles, because continued downsizing of large cars will squeeze V-8 engines out of existence. Thus he expects the goals of the Quad-4—better economy than a conventional four-cylinder and more power than a six-cylinder—to proliferate.

This need for a high power density in small engines may revive rotary (Wankel) engines, says Ralph G. Colello, manager of Arthur D. Little's automotive group (Cambridge, Mass.). Wankel engines might prove less costly to manufacture than reciprocating engines because they have fewer moving parts, but high pollutant emissions and poor durability were still nagging problems when GM sidelined Wankel research in the '70s. That program remains in limbo, but Japan's Mazda (Hiroshima) produces a rotary for its RX-7 sports car, and tractor maker Deere & Co. (Moline, Ill.) is working on industrial rotaries.

Nevertheless, the Wankel and other alternatives seem destined to play minor roles for the foreseeable future. Spark-ignited piston engines are entrenched at least through this century, says Colello. "There's still a lot more that engineers can get out of them." □

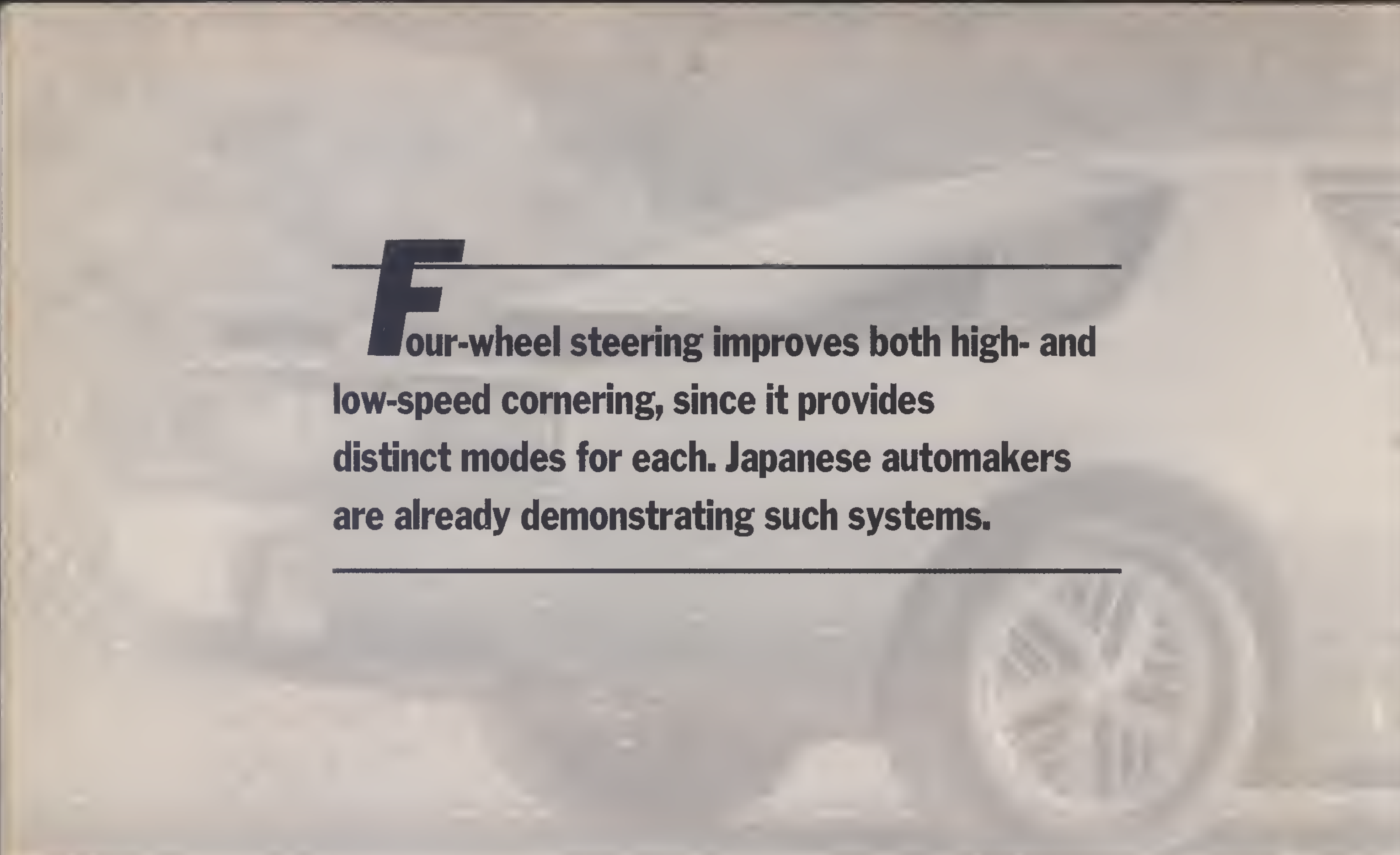
Don Fuller is an automotive writer and auto racer based in Tustin, Cal.

For further information see **RESOURCES**, *p. 69.*

THE CHASSIS GETS CLASSY

by Jeffrey Zygmont

Previous generations of car buyers, particularly in the United States, were preoccupied with size or styling. But today's motorists are clamoring for functional capability. "Technology has become a competitive characteristic in automobiles," says Donald L. Runkle, engineering chief of General



Four-wheel steering improves both high- and low-speed cornering, since it provides distinct modes for each. Japanese automakers are already demonstrating such systems.

Motors' Chevrolet Division (Warren, Mich.). Early in this decade, automakers began to emphasize aerodynamics, engine performance, and dashboard electronics, and now these areas are being complemented by advances in basic systems underneath the car body. Steering, suspension, and traction are suddenly in a renaissance as manufacturers in the U.S., Europe, and Japan reexamine the ways their cars handle the road.

Among the most significant innovations in chassis design are four-wheel steering (which makes the car more maneuverable at low speeds and more stable during high-speed cornering), adjustable suspensions (which automatically change a car's spring characteristics to suit immediate driving needs), and all-wheel drive and other traction control systems (which distribute engine power to the wheels that have the best road grip at any given time).

Although they weren't the subject of much marketing hype in the past, chassis systems were never neglected by automakers; traction, suspension, and steering must be precisely configured for vehicle safety. The present wave of innovation is simply the result of advances in digital control. "From a mechanical standpoint, we've always been able to use the rear wheels for steering," says David Hall, product plans manager of Ford Motor's Ford Division (Dearborn, Mich.). "But today we have the component we always lacked: The logic to turn those wheels when we want to, and not to turn them when we don't want to."

Most earlier uses of microprocessors in autos merely enhanced existing features; electronic engine control, for example, improved motors' performance, but it did not fundamentally change their operation. Alterations in traction, steering, and suspension systems, however, are shaping up to be more radical.

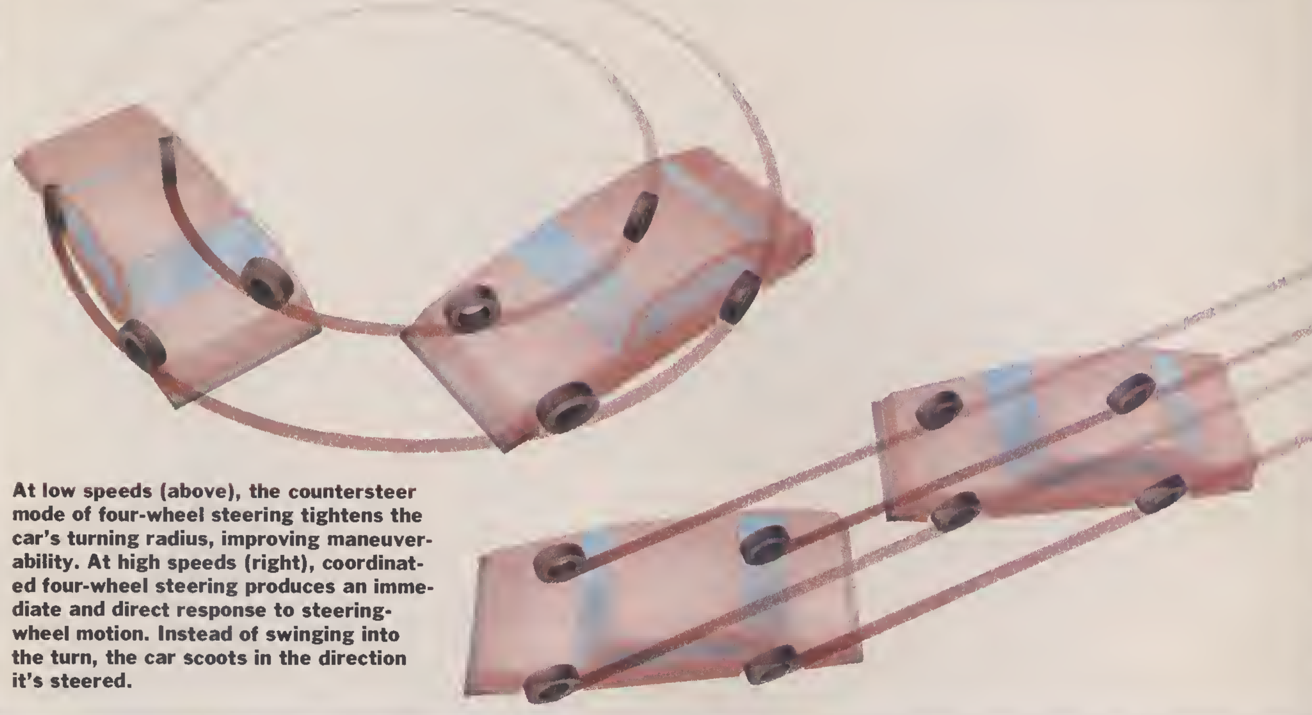
For instance, adjustable suspensions use a central processing unit to interpret signals—such as the amount of brake pressure and steering wheel torque being applied by the driver, as well as vehicle speed, deceleration, and other sensor inputs—in order to determine that the driver is in an evasive maneuver when, say, a child has darted into the street. The computer then signals actuators to stiffen the shock absorbers (in effect, bracing the car) to increase its stability. All of this occurs within milliseconds after the first hint of evasive driving has been detected by the system. The net result of such developments is a car that does more for its driver: With adjustable suspension it can ride softly and comfortably, and still be rigid and stable when necessary.

Steering. From a driver's perspective, the most dramatic of the new automobile developments is four-wheel steering, because it so radically changes a car's maneuverability. Several Japanese automakers are already demonstrating systems, while U.S. and European companies lag behind.

In order for conventional front-wheel steering to provide enough rotation for sharp turns, the front wheels need a great deal of clearance within their fenders. This reduces the front-end space under the hood, ultimately depriving the occupants of leg room. The problem has grown more critical with today's downsized cars. But more important than space considerations, front steering cannot quite reconcile the different dynamics involved in high-speed and low-speed turning.

When a car creeps through parking lots or around obstacles, the front wheels align directly in the path of the turn and simply pull the rear wheels through. At such low speeds, the primary limit to turning radius is the amount of front-wheel rotation permitted by body clearance. But at higher speeds, cornering is much more complex, since it must coordinate the car's forward momentum with its angular acceleration. The result is a kind of controlled skid, in which the front tires are pointing toward the turn while the car body is still moving forward. This creates a lateral force tugging the front of the car toward the turn. Then comes yaw—body rotation around a vertical axis through the car's center of gravity—which pulls the rear wheels into the

Four-wheel steering



At low speeds (above), the countersteer mode of four-wheel steering tightens the car's turning radius, improving maneuverability. At high speeds (right), coordinated four-wheel steering produces an immediate and direct response to steering-wheel motion. Instead of swinging into the turn, the car scoots in the direction it's steered.

curve, putting the vehicle in its steady-state turn. To come out of the turn, this three-step process must be repeated—lateral force at the front tires, which produces yaw, which produces lateral force at the rear tires—adding up to a delay in steering response at high speeds.

Four-wheel steering improves both high- and low-speed cornering by providing distinct modes for each. For parking and close-quarters maneuverability, rear wheels countersteer, or turn in the opposite direction of the front wheels, to provide optimal turning radius. Above a predetermined speed, the system's control module is programmed to turn the rear wheels in the same direction as the front wheels, for faster steering response. "If the rear wheels are controlled properly, vehicle rotation around the center of gravity is no longer needed and the car can start turning the moment the steering wheel is operated," reported engineers from Honda (Tokyo) at a February meeting of the Society of Automotive Engineers in Detroit.

Testing four-wheel steering in its Prelude, Honda found it could use mechanical linkage to "simulate" the control of a microprocessor. Rather than changing rear-wheel steering direction according to vehicle speed, Honda's mechanical connections countersteer when the front-wheel turning angle is large, since this is characteristic of steering at low speeds. When the front-wheel turn angle is less—as in high-speed steering—the rear wheels turn in the same direction. "A major advantage of the steer angle–based four-wheel steering system," reported the Honda engineers, "is that it can be put into a solid form with a combination of comparatively simple mechanisms: Neither electronic nor hydraulic control is required."

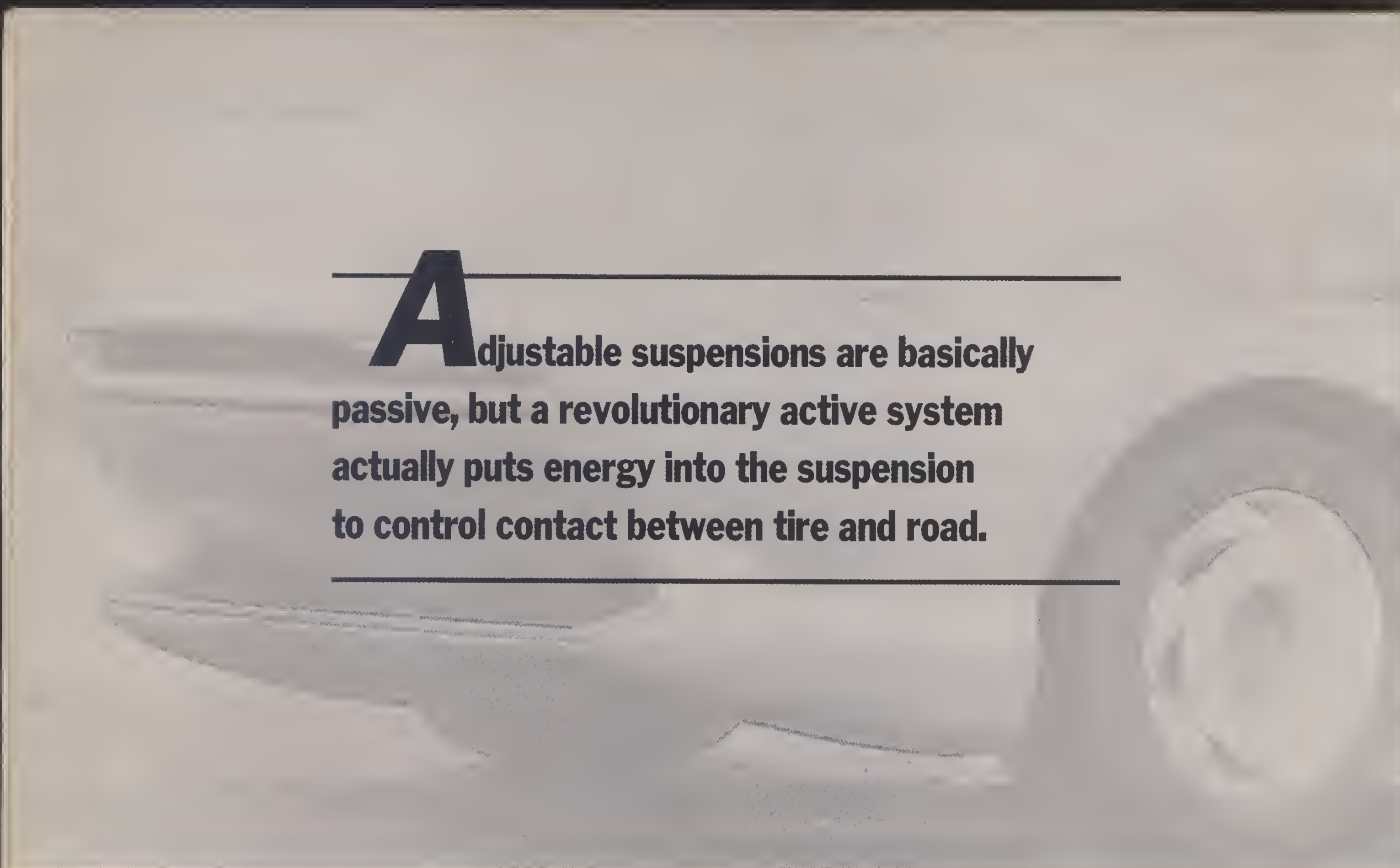
Demonstrating four-wheel steer on its MX-03 experimental car, Mazda Motors of Hiroshima uses a microprocessor to control hydraulically activated rear-wheel motion. Wheels turn 6° either counter to or in the same direction as the front, changing modes at 25 mph. In both modes, the amount of rear-wheel rotation depends on the front-wheel angle measured by a sensor.

The Cue-x concept car from Nissan (Tokyo) uses countersteer only, programmed to operate below 35 mph. The rear wheels are turned by a hydraulic cylinder powered by the front-end system's power-steering pump. The flow of hydraulic fluid to the rear cylinder is controlled by a proportioning valve in the pump that varies output according to steering-wheel angle. When the front wheels are at full turn, the valve permits the maximum rear-wheel rotation, 7°.

This angle may not sound like much, but Richard Hoffman, director of engineering at Nissan's U.S. sales subsidiary in Gardena, Cal., explains that with countersteer, rear- and front-wheel turning angles are directly additive. Thus, for a small car with a 37° front turning angle, 7° of countersteer in the rear wheels permits a total steering angle of 44°. In practical terms, says Hoffman, this means a car ordinarily needing three lanes for a U-turn can do it in only two lanes.

The widely publicized Dynamic Tracking Suspension System on the Mazda RX-7 two-seater sports car is being promoted as four-wheel steering, but is really just a new application of rear-wheel compliance steer. As on all automobiles, RX-7 suspension members are attached to the car frame with stiff rubber bushings that have just enough play to help isolate the car from road shocks. Compliance steer capitalizes on this play, configuring rear suspension geometry to react to cornering force by moving the rear wheels into an alignment that is more stable during turns. In the absence of cornering force, the rear wheels maintain an alignment for straight-ahead driving.

This passive approach is decades old. Reacting to the marketing hoopla over Mazda's system, an official of the German luxury-car manufacturer Daimler-Benz (Stuttgart) observed that Mercedes cars "have always done that." But a new system from Nissan gives the Japanese automaker undisputed leadership in *active* compliance steer. Nis-



Adjustable suspensions are basically passive, but a revolutionary active system actually puts energy into the suspension to control contact between tire and road.

san's High Capacity Active Controlled Suspension uses hydraulic cylinders to force rear wheels into immediate compliance during turns, rather than waiting for cornering forces to affect wheel geometry. As in passive systems, movement is very slight—Nissan takes advantage of the half degree of distortion permitted by the rubber suspension bushings. The system—incorporated in the Skyline model sold in Japan, as well as in the Cue-x and the Mid-4 sports car prototype—is controlled by a microprocessor that digests data from vehicle speed and steering wheel sensors. On the Cue-x, this control unit coordinates the active compliance with the countersteer.

Suspension. Vehicle suspension has many roles: It absorbs vibrations from road irregularities, maintains balanced tire contact with the road for sure traction and control, responds to changes in vehicle weight (as when passengers pile in), and reacts to inertial changes during cornering, braking, and accelerating.

Doing one of these tasks well usually means compromising another. For example, soft suspensions isolate the vehicle's occupants from rough roads, but they are less stable because the play that they allow results in extreme vertical wheel movement, disrupting contact between road and tires. Worse yet, the disruptions often occur in severe driving situations, when stability is most critical.

Adjustable suspension systems are able to bridge that compromise by using electronics to alter the amount of resistance in the shock absorbers. Japanese carmakers lead in these systems. The Electronic Modulated Suspension from Toyota (Toyota City, Japan) is controlled by a microprocessor that uses inputs on vehicle speed, steering angular velocity, and throttle, brake, and transmission status to regulate shock absorbers between soft, medium, and firm. A similar adjustable system on Mazda's newly redesigned 626 sedan switches damping modes in a fiftieth of a second. Both Mazda and Toyota provide a dash switch that enables the driver to override the automatic system, setting the shocks in either a sporty or a normal mode.

Nissan reaches a higher level of sophistication by adding a road condition sensor. This ultrasonic sonar transceiver under the front bumper measures the height of the car's body from the road, allowing the central processor to adjust shock settings accordingly. For example, when Nissan's Bluebird Maxima—a luxury model sold in Japan—is traveling straight ahead at moderate speed on a smooth road, a soft ride is maintained for comfort. But when the car approaches a dip in the road, the sonar detects the undulation before the front wheels reach it. Before stiffening the shocks to maintain stability and control as the suspension absorbs the impact, the microprocessor permits a brief delay for the front wheels to traverse the dip, sparing riders an uncomfortable jolt. The rear shocks are firmed after a further delay, giving the rear wheels time to cross the dip.

Adjustable suspensions are basically passive, reacting to dynamic changes by varying the amount of energy they can absorb. But a revolutionary active suspension concept developed by Lotus Engineering of Norwich, England, actually puts energy into the suspension system to control contact between wheel and road. Still in prototype, the system has been successfully demonstrated on a Formula 1 racer and the Lotus Esprit high-performance road car. It will be exhibited in the Corvette Indy, a show car Lotus is building for General Motors' Chevrolet Division.

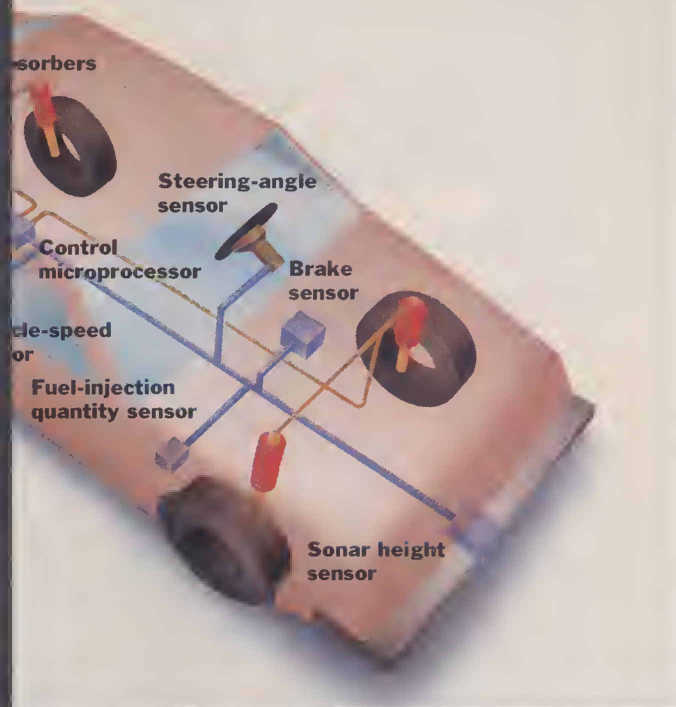
Lotus eliminates springs and shock absorbers altogether, replacing them with hydraulic cylinders that synthesize the movement of conventional suspensions. The system's microprocessor gets data from sensors in each of the four wheel actuators; other sensors monitor lateral and forward accelerations. On the basis of these inputs, the system automatically moves each wheel vertically in relation to the body—just as passive suspensions yield in response to road irregularities, changes in speed and direction, and

The Answer is:

No one.

Find the question in this issue.

Sonar-controlled suspension



uld allow smaller actuators enable the car to "limp he active system failed. Lotus sts reducing power demand ing "smart pumps" that sup- lic pressure only on demand. nal hydraulic pumps such as in power steering run con-

Lotus's system is the most licized, "all the major Euro- companies have programs suspension," says Michael ctor of the Automotive Divi- S Consultancy Group, a re- in London, England. So far, tive systems are the province kers in Europe, where road are more variable and high- re permitted. U.S. and Japa- facturers are concentrating ble suspensions instead.

ile height control is another suspension development. ar sags from passengers or ension geometry is ordinari- out of alignment. Ford tack- lem on its Lincoln Mark VII pension system in which in- r bags replace steel springs. ht relative to the wheels is by height sensors on each l and the rear axle. A com- rols an electric air compres- the hood, inflating or bleed- r bags for front-to-rear and leveling. Several Japanese automakers use the same method, but with the air bags augmenting steel springs. In its Cue-x concept car, though, Nissan follows Ford with a full air suspension. And Toyota's FXV experimental car uses the system to automatically crouch at high speeds to improve aerodynamic efficiency.

Traction control. In addition to keeping wheels on the road through sophisticated suspensions, automakers are improving traction by better managing torque output at the wheels themselves. All-wheel drive is currently the most popular way to do this; even the otherwise ordinary Ford Tempo will sport all-wheel drive next year. And at the Tokyo Motor Show last fall, more than 40 all-wheel-drive models were exhibited. PRS's Smith estimates that within a few years all-wheel-drive cars may account for about 15% of Europe's annual production. A similar proportion of the U.S. car market is also expected to go to all-wheel drive.

Although descended from four-wheel drive systems in trucks—where the driver shifts between two- and four-wheel drive—most of the latest all-wheel drives for passenger cars are full-time systems, permanently splitting drive torque between front and rear wheels. West Germany's Audi (Ingolstadt) and the Subaru division of Fuji Heavy Industries (Tokyo), world lead-

Adjustable suspension
passive, but a revolutionary ac
actually puts energy into the s
to control contact between tir

san's High Capacity Active Controlled Suspension uses hydraulic cylinders to force rear wheels into immediate compliance during turns, rather than waiting for cornering forces to affect wheel geometry. As in passive systems, movement is very slight—Nissan takes advantage of the half degree of distortion permitted by the rubber suspension bushings. The system—incorporated in the Skyline model sold in Japan, as well as in the Cue-x and the Mid-4 sports car prototype—is controlled by a microprocessor that digests data from vehicle speed and steering wheel sensors. On the Cue-x, this control unit coordinates the active compliance with the countersteer.

Suspension. Vehicle suspension has many roles: It absorbs vibrations from road irregularities, maintains balanced tire contact with the road for sure traction and control, responds to changes in vehicle weight (as when passengers pile in), and reacts to inertial changes during cornering, braking, and accelerating.

Doing one of these tasks well usually means compromising another. For example, soft suspensions isolate the vehicle's occupants from rough roads, but they are less stable because the play that they allow results in extreme vertical wheel movement, disrupting contact between road and tires. Worse yet, the disruptions often occur in severe

driving situations, when
most critical.

Adjustable suspension sy
able to bridge that comprom
electronics to alter the amou
tance in the shock absorber
carmakers lead in these sy
Electronic Modulated Susp
Toyota (Toyota City, Jap
trolled by a microprocesso
inputs on vehicle speed, ste
lar velocity, and throttle,
transmission status to regu
absorbers between soft, m
firm. A similar adjustable
Mazda's newly redesigned
switches damping modes in
a second. Both Mazda and
vide a dash switch that e
driver to override the aut
tem, setting the shocks i
sporty or a normal mode.

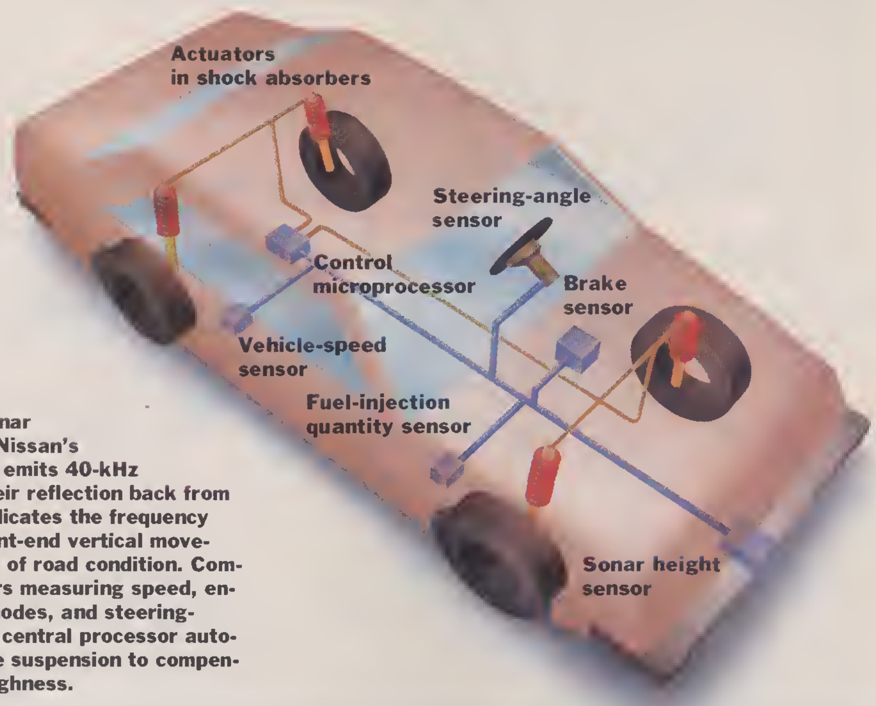
Nissan reaches a higher
phistication by adding a roa
sensor. This ultrasonic sona
er under the front bumpe
the height of the car's bod
road, allowing the central
adjust shock settings accor
example, when Nissan's Blu
ma—a luxury model sold i
traveling straight ahead a
speed on a smooth road, a
maintained for comfort. Bu
car approaches a dip in th
sonar detects the undulatio
front wheels reach it. Befor

The Answer is:

No one.

Find the question in this issue.

Sonar-controlled suspension



The ultrasonic sonar height sensor in Nissan's Bluebird Maxima emits 40-kHz pulses, timing their reflection back from the road. This indicates the frequency and extent of front-end vertical movement—a measure of road condition. Combined with sensors measuring speed, engine and brake modes, and steering-wheel position, a central processor automatically sets the suspension to compensate for road roughness.

exterior wind forces.

But unlike the passive suspensions, the active system can make the most appropriate wheel-position change to maintain both a smooth ride and optimum dynamic stability. By precisely controlling suspension height in a turn, for instance, the system eliminates body roll—the destabilizing tendency of a car body to roll toward the outside of a turn, unloading the inner wheels. The prototype system is claimed to net a 10% increase in the speed at which cars can negotiate turns.

In its current form, the system appears exotic, but Patrick Peal, operations manager of Lotus's active suspension program, says that an active suspension could eventually simplify manufacturing and reduce the cost of production cars. A Buick Skyhawk and a Buick Century, for instance, require radically different suspension hardware. But an active system could conceivably allow them to share common parts, programmed separately to compensate for their dynamic differences.

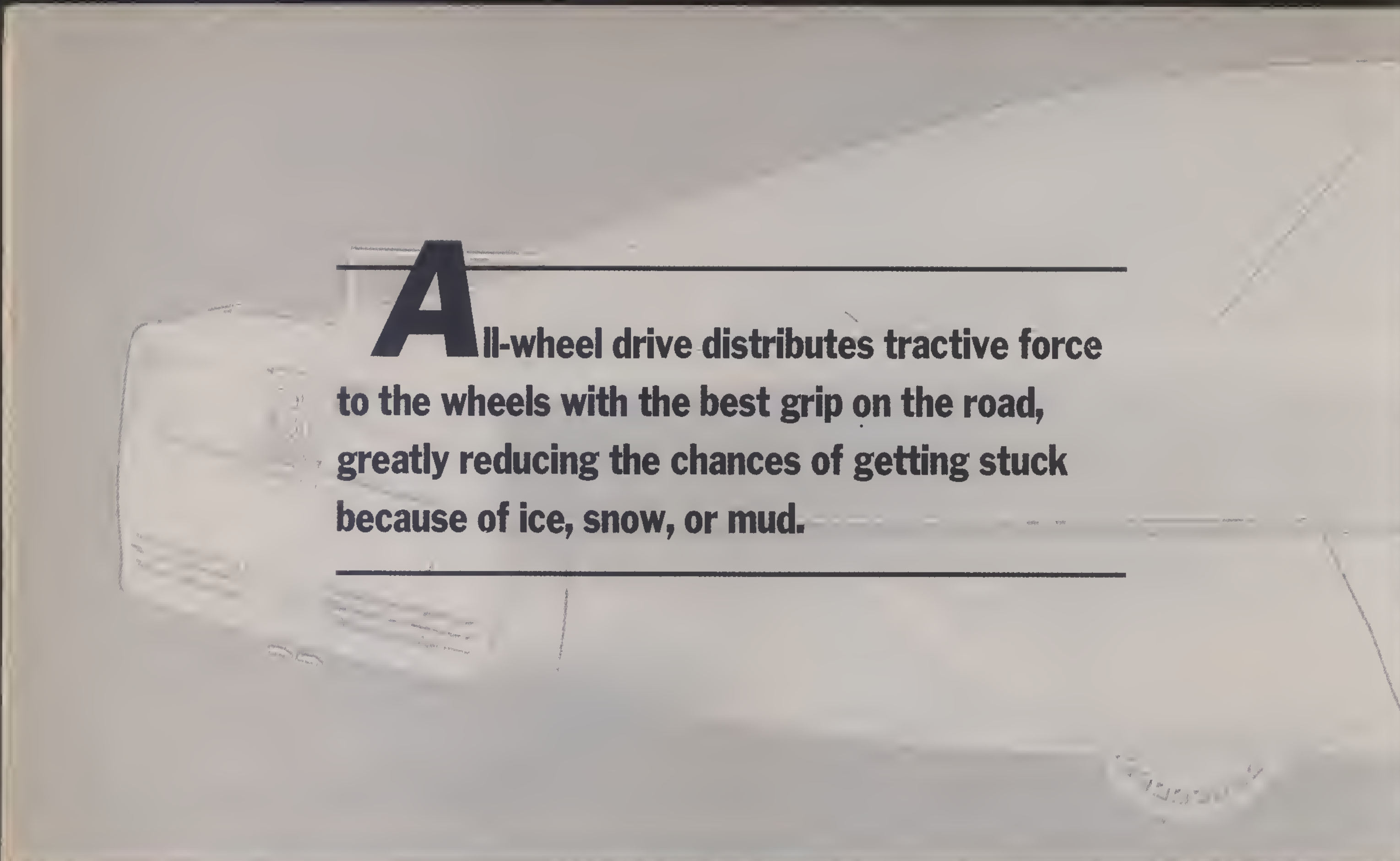
A problem with active suspensions is that they eat up power. Lotus supplies hydraulic pressure to its actuators by a pump driven off the engine. This scavenges horsepower, sacrificing fuel economy and, particularly in smaller cars, reducing energy available for propulsion. Lotus proposes passive springs installed in parallel with the actuators. By doing some of the support work, the springs would allow smaller actuators and would enable the car to "limp home" if the active system failed. Lotus also suggests reducing power demand by developing "smart pumps" that supply hydraulic pressure only on demand. Conventional hydraulic pumps such as those used in power steering run continuously.

Though Lotus's system is the most highly publicized, "all the major European car companies have programs on active suspension," says Michael Smith, director of the Automotive Division at PRS Consultancy Group, a research firm in London, England. So far, he says, active systems are the province of automakers in Europe, where road conditions are more variable and higher speeds are permitted. U.S. and Japanese manufacturers are concentrating on adjustable suspensions instead.

Automobile height control is another important suspension development. When a car sags from passengers or cargo, suspension geometry is ordinarily pushed out of alignment. Ford tackles the problem on its Lincoln Mark VII with a suspension system in which inflatable air bags replace steel springs. Body height relative to the wheels is measured by height sensors on each front wheel and the rear axle. A computer controls an electric air compressor under the hood, inflating or bleeding the air bags for front-to-rear and side-to-side leveling. Several Japanese automakers use the same method, but with the air bags augmenting steel springs. In its Cue-x concept car, though, Nissan follows Ford with a full air suspension. And Toyota's FXV experimental car uses the system to automatically crouch at high speeds to improve aerodynamic efficiency.

Traction control. In addition to keeping wheels on the road through sophisticated suspensions, automakers are improving traction by better managing torque output at the wheels themselves. All-wheel drive is currently the most popular way to do this; even the otherwise ordinary Ford Tempo will sport all-wheel drive next year. And at the Tokyo Motor Show last fall, more than 40 all-wheel-drive models were exhibited. PRS's Smith estimates that within a few years all-wheel-drive cars may account for about 15% of Europe's annual production. A similar proportion of the U.S. car market is also expected to go to all-wheel drive.

Although descended from four-wheel drive systems in trucks—where the driver shifts between two- and four-wheel drive—most of the latest all-wheel drives for passenger cars are full-time systems, permanently splitting drive torque between front and rear wheels. West Germany's Audi (Ingolstadt) and the Subaru division of Fuji Heavy Industries (Tokyo), world lead-



All-wheel drive distributes tractive force to the wheels with the best grip on the road, greatly reducing the chances of getting stuck because of ice, snow, or mud.

ers in all-wheel-drive passenger cars, use a center differential to divide power between front and rear. Commonly employed to split torque between the two drive wheels of rear-drive cars, a differential is a gear set that allows the two wheels to turn at different speeds; when cornering, the inside wheel, traveling less distance than the outer one, rolls more slowly. In four-wheel-drive cars, the center differential frees the front and rear tires to turn at different rates, since they also cover different turning radii in cornering.

But differential gears divert torque to the wheel with the least road friction. That works fine on a good road surface, where all four tires have an equal grip. But if one tire is on ice, it consumes all engine rotation, spinning furiously while the tires with good traction at the other side of the differential don't turn at all.

To remedy this, Audi and Subaru provide differential locks the driver can activate in slippery conditions to rigidly set the torque distribution between axles. As a result, both a front wheel and a back wheel have to spin for the car to get stuck. Audi further provides a driver-controlled lock for the rear differential, which splits the rear-axle torque between rear wheels. With both rear and middle differential locked, three tires would have to lose traction for the car to get stuck—an unlikely occurance. The Mercedes 4-Matic all-wheel drive, scheduled to debut in Europe in January and in the U.S. by late 1987, also uses differential locks, but they are controlled by a microprocessor instead of by the driver.

Unfortunately, these mechanically coupled all-wheel-drive systems provide a 50/50 torque split even when it's unneeded, such as during dry weather and straight-ahead driving. Then the extra energy used to turn the system's hardware is wasted. Also, they can never get more than 50% torque to either axle.

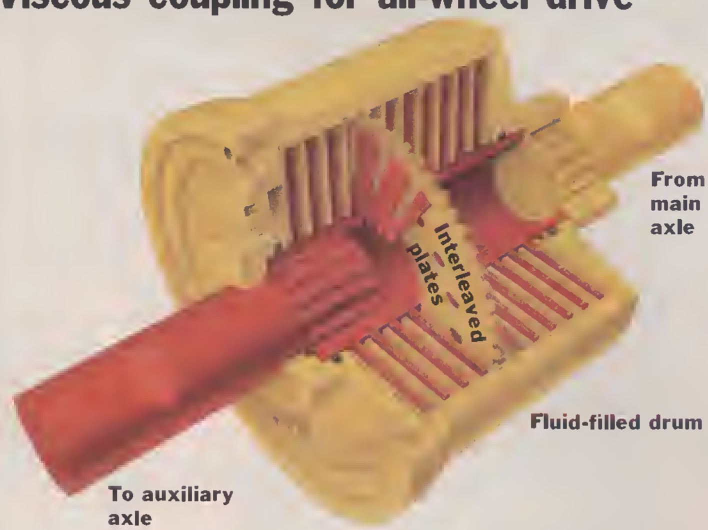
Volkswagen (Wolfsburg, West Germany) and Nissan solve these problems with automatic fluid-coupled differentials that provide power to the auxiliary axle only as needed. Recently introduced on its Vanagon models and on the Golf in Europe, VW's Syncro fluid coupling consists of two interleaved sets of parallel plates: One set is connected by a shaft to the drive axle; the other set transmits torque by a shaft to the auxiliary axle. (On the Vanagon the drive axle is at the rear; on the Golf, it's at the front). The plates are sealed inside a drum filled with a silicon fluid that increases in viscosity as its temperature rises.

In good driving conditions, when the Vanagon's front and rear wheels are turning at the same speed, the plates do likewise. With no slip between plates, the viscosity of the fluid remains low and minimal power is transferred from rear to front; the van is 95% rear-drive. However, if the rear wheels loose traction and begin to spin, they rotate faster than the front wheels. Thus the plates connected to the rear axle spin faster than those joined to the front, cutting through the fluid in the coupler. This raises the fluid's temperature, inceasing its viscosity and thus its resistance to shearing. Therefore the fluid rotates at the speed of the faster-moving set of plates, pulling the slower-moving set with it and hence transferring some of the drive torque from rear to front.

If rear-wheel spin is sufficient, lockup—and complete torque transfer—can occur in about a tenth of a second, or a quarter of a tire revolution, according to VW. The level of slip maintained between plates depends on the speed difference between front and rear axles. If the traction loss at the rear axle is small, slip between plates will be less, so only a small amount of drive torque will be transmitted through the coupler. In other words, the amount of torque transferred to the auxiliary axle is infinitely variable, depending on the traction of the main drive axle. Nissan has a similar system in its Mid-4 prototype.

Other all-wheel-drive systems use variations on mechanical or hydraulic torque control. In Mazda's MX-03, the viscous differential is controlled by the driver. When the operator selects a front/rear power split via a dash-mounted dial, a pump maintains the

Viscous coupling for all-wheel drive



In Volkswagen's viscous coupling for continuously variable all-wheel drive, one set of plates attaches to a rotating outer drum that is connected to a shaft from the main axle. The second set connects to an inner rotating shaft leading to the auxiliary axle. When more traction is needed, silicon fluid binds the plates together, transferring power from main to auxiliary axle.

necessary fluid pressure for torque transfer between plates. Nissan's Cue-x uses a control computer to vary the grip of mechanical clutch plates joining front and rear shafts, automatically adapting the torque split to driving conditions.

Whether viscous or mechanical, all-wheel-drive systems consume space. The bodies of Vanagons equipped with Syncro, for instance, are raised an inch to accommodate the system. Thus several companies, like BMW (Munich) and Volvo (Gothenburg, Sweden), are aggressively developing better two-wheel traction control. Aside from the space savings, two-wheel drive with traction control is lighter (and hence more fuel-efficient) and less expensive.

Already the West German component supplier Robert Bosch is marketing a traction control system, used by Mercedes, that relies on electronic control to prevent drive wheels from losing traction. During acceleration, the microprocessor reads wheel speed, as reported by rotational velocity sensors, to detect a spin. The computer then reduces engine speed until the spinning wheel slows down enough to regain traction. This way the system maintains the maximum engine speed the wheels can handle, even if the driver tries to accelerate harder.

To do this, Bosch overrides the accelerator pedal by eliminating its mechanical link to the engine. Instead, a "fly-by-wire" electronic pedal converts the amount of depression into an electrical impulse for the fuel system computer. Thus the pedal becomes nothing more than another engine management sensor, monitoring the intentions of the driver. Bosch reasons that the computer can control wheel grip better than the driver, thus maintaining good traction even in two-wheel-drive cars.

Chassis developments are only part of the push for new technology, joining advanced engines, communication systems such as cellular telephone and satellite navigation, and sophisticated cabin and dashboard features. The dizzying rate of innovation is reflected in advertising blitzes that focus on arcane technological features such as the number of valves in an internal combustion engine. "A year ago nobody knew what an engine valve was. Now everybody has to have 16 of them," says GM vice-president Robert Stemple.

By satisfying the public's appetite for new technology, carmakers are out to increase profits as sales volume stabilizes. "The hope of the product planner is to sell the same number of cars in the future, but for more money," says James Womack, research director of MIT's Future of the Automobile II program. The U.S. market is considered mature at its current level of about 10.5 to 11 million new automobiles annually, and new imports will prohibit growth, he says.

All-wheel drive is already popular in areas like Scandinavia and the Rocky Mountains, where adverse driving conditions make it a significant safety feature. But other advanced chassis systems such as four-wheel steering and active suspension are still under development and have yet to be tested in the market.

"Safety is what will make the broad application of all these systems possible," says Ford's Hall. Right now they are generally regarded as high-performance options because of their cost and exotic appeal, he says, but ironically the true "performance driver" rejects features that compromise his direct control of the car. "The real benefit is to the everyday driver who sometimes gets into driving situations that are beyond his ability to control."

The biggest challenge to automakers now is how to offer such equipment at an attractive price. But they are optimistic. "With the breakthroughs in electronics and the way our costs are going down," says Hall, "we can begin to make these features affordable." □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

Electronics adds sizzle to auto market

Electronic components already play a significant role in today's automobiles, a role that should expand rapidly in the next few years. The electronic content of 1985-model cars was worth an average of $585; this figure could reach $1383 by 1995, according to Ford Motor (Dearborn, Mich.). "The cost of electronics has traditionally dropped by as much as 50% per year," notes Lawrence T. Harbeck, associate research scientist at the University of Michigan's Transportation Research Institute (Ann Arbor). "Thus, while the value of auto electronics will more than double over the next ten years, there could be five to ten times more electronic components."

The 1985 worldwide merchant market just for semiconductors used in automobiles was $1.3 billion, according to James Edson, market development manager at Motorola's Semiconductor Products Sector (Phoenix). "This market will grow at a compound rate of 20% annually for the foreseeable future," he predicts.

Demand for integrated circuits is strengthening ties between the auto industry and electronics manufacturers such as Motorola, Intel (Santa Clara, Cal.), and TRW's Transportation Electronics Group (Farmington Hills, Mich.). General Motors' Delco Electronics Division (Kokomo, Ind.) supplies some of the electronics for its parent company.

The first substantial use of electronics in cars, beyond stereo radios and tape decks, was prompted by federal emissions standards that took effect in the late 1970s. "With their precise handling of air/fuel mixtures, electronically driven engine controls represented the only way Detroit could meet both the required standards and driver expectations for peppy engine performance," says Ralph Colello, manager of the Automotive Group at Arthur D. Little (Cambridge, Mass.). "That changed the mindset of Detroit engineers from mechanical to electronic. Now the technology for every auto subsystem is up for grabs."

However, not every new component will necessarily win customer approval just because it is electronic. Nissan, Chrysler, and GM, for example, are trying to market voice synthesis devices in some models, but "people don't like to be nagged by their cars," observes Colello. The kind of electronic products that will be widely installed, he contends, are those offering cost savings to automakers and performance to customers.

> ***"Electronic components have already proven themselves in auto powertrains. Now they are emerging in braking, steering, and suspension systems, resulting in a significant improvement in the safety and handling of cars."***
>
> ***Edward Groszek***
> ***Technical Planning Manager***
> ***Electrical & Electronics Div.***
> ***Ford***

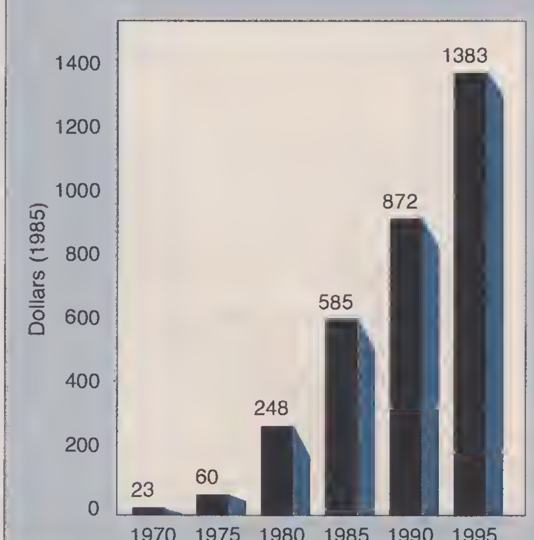
Antilock braking systems, for instance, use wheel-mounted sensors to detect when wheels quickly decelerate, and then automatically relieve brake pressure to prevent skidding. This product, whose cost to the automaker has dropped from $1000 to $500 over the past five years, is available commercially from West German firms Robert Bosch and Alfred Teves (an ITT subsidiary); General Motors' Delco Moraine Division and Allied's Bendix Division (Southfield, Mich.) are working on their own versions. Antilock systems are now being used in Mercedes-Benz cars, various top-of-the-line General Motors and Ford models, and some Japanese cars.

Electronically controlled suspensions are also finding their way into some models of such automakers as Chrysler, Toyota, Mitsubishi, and Mazda. These systems maintain the load level of a car and adjust the rate at which the car absorbs road impacts. Electronic components are also under development for traction controls and for steering systems that greatly improve maneuverability.

Car radios are part of a growing group of electronics applications that are the most visible to drivers. "In luxury cars, audiophile high-performance stereo systems, which include compact disc players, have taken the industry by storm," says Leonard Groszek, technical planning manager at Ford's Electrical and Electronics Division (Dearborn, Mich.). Dashboard displays and cellular telephones are other notable electronic features. A few models already have such products as rear-view mirrors that adjust to nighttime driving automatically, advanced climate-control equipment, and on-board diagnostics.

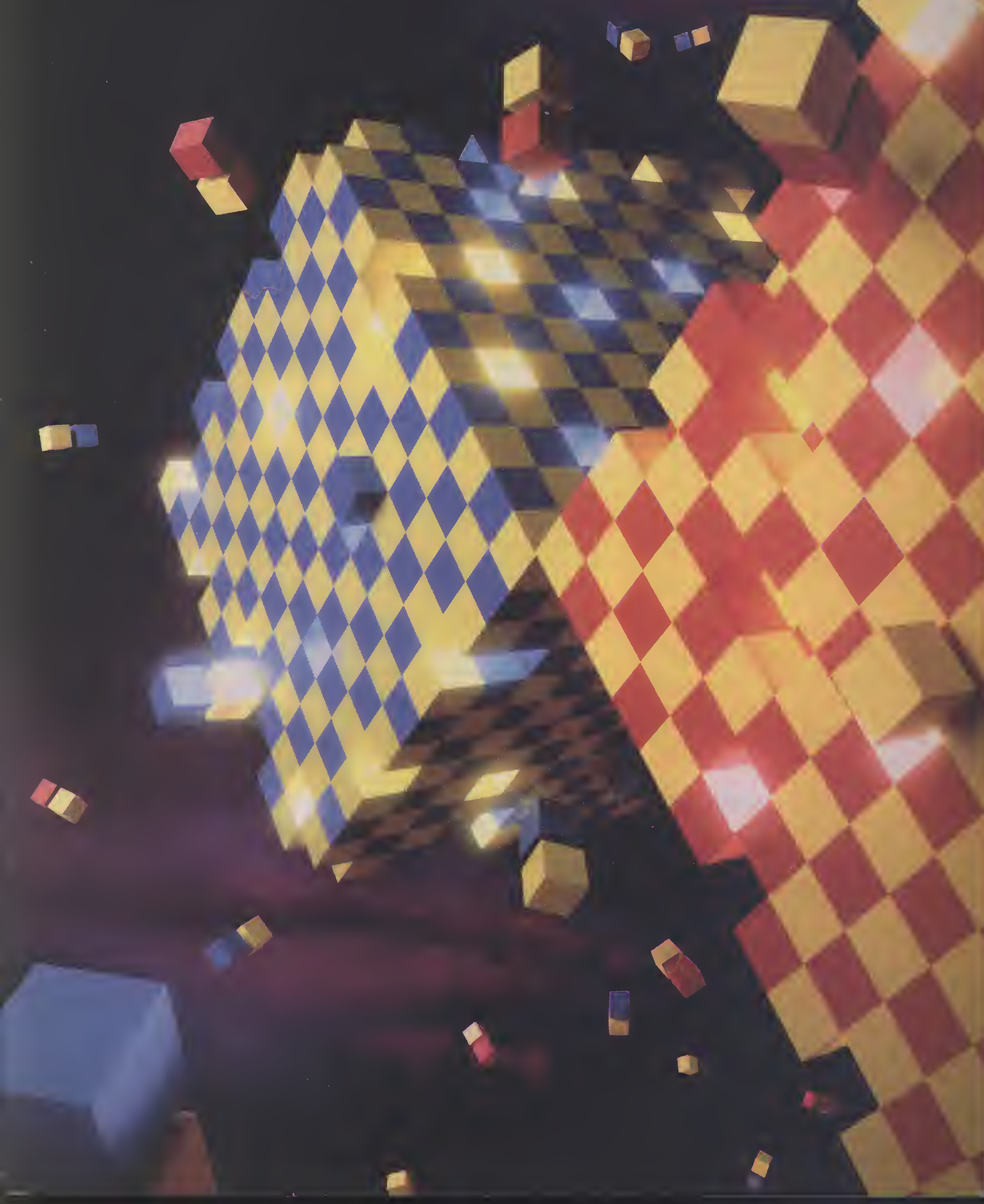
"Most of these improvements are appearing first in luxury models," says Arthur D. Little's Colello. "But they are likely to move into midrange cars before long in response to a number of complementary factors. Automakers are interested in electronic features as a way of differentiating their products in an increasingly competitive and crowded market. As the production volume of electronic components rises, their price will decrease. And more consumers will want to enjoy the performance benefits electronics bring to the car." ***—Nicholas Basta***

Electronic content per car



SOURCE: FORD MOTOR COMPANY

The Normalization Pairing



The Normalization Pairing

A scientist at the General Motors Research Laboratories has developed a new method for accurately determining the effectiveness of safety belts in preventing traffic fatalities. The approach may be used to answer a wide variety of questions using data bases that lack conventional measures of exposure.

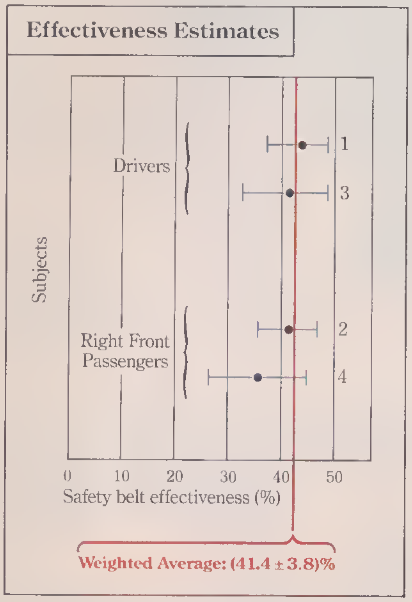
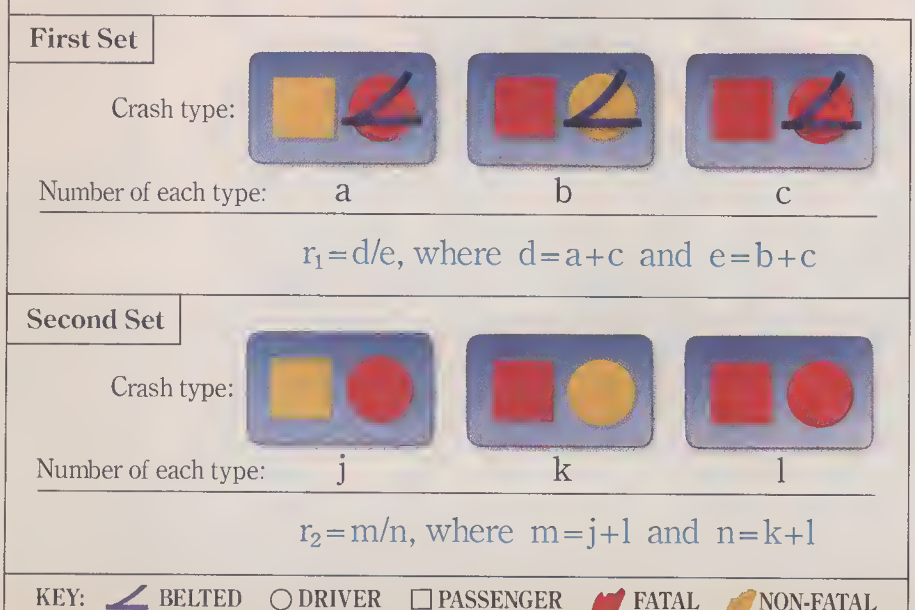


Figure 1: Weighted estimates of safety-belt effectiveness by subject, with standard error. Estimate 1 pairs subjects with right-front passengers; 2 pairs subjects with drivers; 3 and 4 pair subjects with occupants of all other seating positions.

Figure 2: Schematic representation of a sample double-pair comparison.



THERE IS A serious problem that researchers often encounter when trying to analyze large collections of information. It is the problem of measuring exposure. Though a collection of data may contain a large number of cases, and though the facts in each case may be highly detailed, there may be no way of comparing events selected for inclusion in the collection against the normal occurrence of similar events in the world at large.

One such data base is the Fatal Accident Reporting System (FARS) maintained by the U.S. Department of Transportation's National Highway Traffic Safety Administration. FARS details all fatal accidents in the U.S. since January 1, 1975—more than 300,000 crashes. However, it lacks an explicit measure of exposure.

FARS contains, for example, the number of fatalities classified by safety belt use. But fatalities among users depend on two considerations: first, the effectiveness of safety belts; and second, the crash involvement differences between users and non-users—that is, the exposure of belt users to crash involvement. If crash involvement were independent of belt use, it would be a simple matter to calculate the effectiveness of safety belts in preventing fatalities. However, belted drivers have fewer crashes, and the crashes they do have tend to be of lower average severity than those of unbelted drivers.

Now a scientist at the General Motors Research Laboratories has developed an approach to drawing inferences from FARS using only the information contained in the file. Dr. Leonard Evans has designed a method for comparing the effects of isolated characteristics by using two sets of crashes. In each set, a *subject* occupant is paired with an *other* occupant. In the first set, the subject exhibits the characteristic to be studied; in the second, the subject does not. The *other* occupant is chosen to have similar characteristics in both sets of crashes (e.g. always unbelted), and thereby acts as a measure of exposure.

To illustrate the workings of the method of double-pair comparison, Dr. Evans first applied it to a study of the effects of safety belt use on fatality risk. He could define the effectiveness of safety belts in terms of the ratio:

$$R_{true} = \frac{N_b}{N_u} = \frac{N' \int q_{D,b}(s) f_u(s) ds}{N' \int q_{D,u}(s) f_u(s) ds}$$

where N' is the number of crashes per year by unbelted drivers, s is crash severity, $f_u(s)$ is the probability that a crash involving an unbelted driver has a severity s, $q_{D,u}(s)$ is the probability that an unbelted driver will become a fatality in a crash of severity s, and $q_{D,b}(s)$ is the probability that a belted driver will become a fatality in a crash of severity s. R_{true} is a ratio of new to

old fatalities—assuming a formerly unbelted population became a belted population, with nothing else changing. But while N_u, the number of unbelted driver fatalities, can be determined from the FARS data, N_b, the number of these who would still have been fatalities had they been wearing safety belts, clearly is not coded in the data base.

Dr. Evans applied the double-pair comparison method to determine a quantity, R, that would, under plausible assumptions, accurately estimate R_{true}. Figure 2 shows the pattern of the first application. In it, one set of crashes paired belted drivers and accompanying unbelted front-seat passengers, generating a ratio, r_1, of belted driver fatalities per unbelted passenger fatality. The second set paired unbelted drivers with unbelted front-seat passengers, leading to a ratio, r_2, of unbelted driver fatalities per unbelted passenger fatality. This yields a value of $R = r_1/r_2$ as a measure of safety-belt effectiveness.

IN ADDITION to calculating R for driver *subjects* using front-seat passenger *others*, effectiveness was also calculated for right-front passenger *subjects* using driver *others*. Additional calculations were made pairing driver or right-front passenger *subjects* with passengers in any other seating position. Figure 1 reflects the synthesis of these estimates. Estimates 1 and 2 represent *subject* and *other* occupants disaggregated into three age categories and averaged. Estimates 3 and 4 represent pairings of *subjects* with occupants in other seating positions and averaged.

In all, Dr. Evans calculated 46 estimates of R. The weighted average of these gives a safety-belt effectiveness of $(41.4 \pm 3.8)\%$. This should be an accurate estimate whenever the distribution of severities is the same for both sets of crashes in each double-pair comparison.

Moreover, a formal analysis showed r_1/r_2 to be an accurate estimate of R_{true} under much less stringent restrictions. Even when the distributions of crash severity differ for belted and unbelted drivers, Dr. Evans concluded that the simple ratio $R = r_1/r_2 = nd/me$ is indeed an accurate estimate of safety-belt effectiveness.

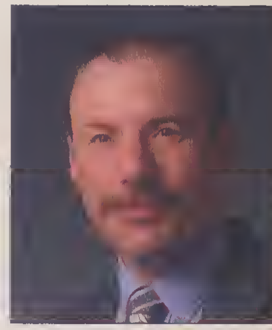
Dr. Evans' confidence in the method rests on some key assumptions. But, as he points out: "One of the beauties of the method is its ability to remove the biasing effects of confounding interactions that may undermine those assumptions. It is necessary only to disaggregate occupants into different categories of the suspect variable.

"Because of bias elimination, and the ability to create a measure of exposure, the method of double-pair comparison lends itself to a broad range of investigations. We can estimate, for example, fatality risk as a function of helmet use by motorcyclists, or safety-belt effectiveness in different accident types. More broadly, we can estimate fatality risk as a function of age, sex, or alcohol use. We may even have revealed a trend in trauma response, in general, as a function of sex and age."

General Motors

MARK OF EXCELLENCE

THE MAN BEHIND THE WORK

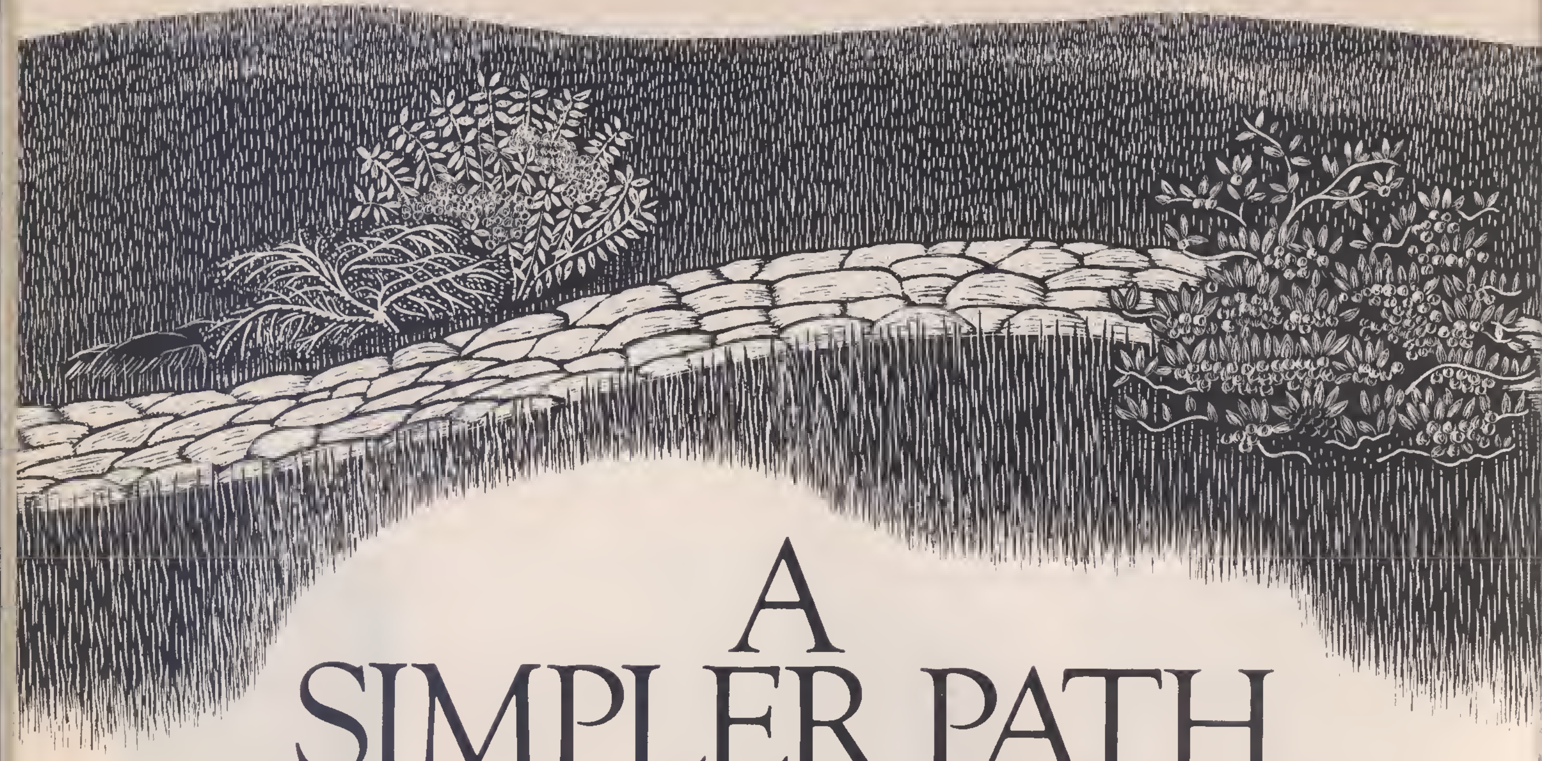


Dr. Leonard Evans is a Senior Staff Research Scientist in the Operating Systems Research Department at the General Motors Research Laboratories.

He received his undergraduate degree in physics from The Queen's University of Belfast, and holds a D. Phil. in the same discipline from Oxford University. He was a Post-Doctorate Fellow at the National Research Council of Canada in Ottawa.

Since joining GM in 1967, Dr. Evans has published research on such diverse topics as atomic physics and trauma analyses. His current area of concentration is traffic safety research.

He is a member of the Human Factors Society and is a Past President of the Society's Southeastern Michigan Chapter. In 1985, Dr. Evans received the Society's A. R. Lauer Award "for outstanding contributions to the human factors aspects of highway safety."



A SIMPLER PATH TO COMPUTING

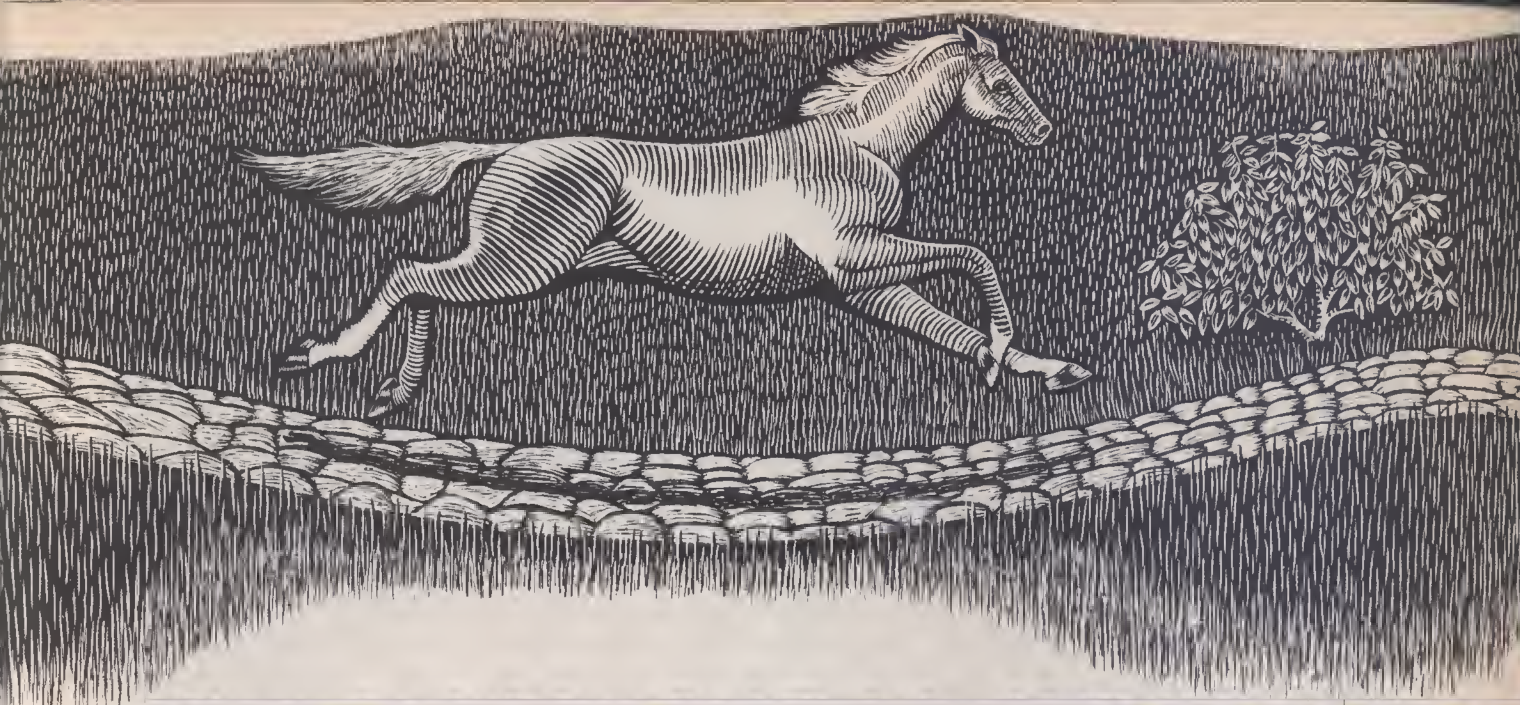
Parallel processing, with its promise of coordinating thousands of processors on a single task, has captured the attention of an unusually broad audience. But a less dramatic architectural change known as RISC—reduced instruction set computing—may have a greater impact on the marketplace in the near term.

IBM (Yorktown, N.Y.), whose research labs pioneered RISC concepts a decade ago, recently joined an array of small companies offering RISC-based computers. And Hewlett-Packard (Palo Alto, Cal.), one of the largest minicomputer manufacturers in the world, has embraced RISC as a foundation for its new generation of high-performance machines.

by Rick Cook

The basic premise of reduced instruction set computing is that machines cost less and run faster if they use a small set of simple instructions to direct their operation. By contrast, the tendency over the years has been to build complex instruction set computers (CISCs), which incorporate large numbers of detailed instructions. But complex instruction sets require more elaborate and more expensive computer hardware, say RISC proponents, and, contrary to their intent, slow the computer down. A complex instruction may take many machine cycles to perform a task that a set of simpler instructions could do in far fewer cycles. RISC critics counter that simple-instruction computers are suitable only for limited uses, cannot easily run software written for existing CISC machines, and, while simplifying hardware design, require more complex software compilers to convert programs into code the computer can understand.

Growing activity. Computer users are trying to sort through these claims and



counterclaims as a growing number of RISC machines vie for their dollars. About 20 companies now offer RISC products, and the addition of IBM and Hewlett-Packard to their ranks has substantially increased their credibility. For its part, Hewlett-Packard hopes to demonstrate that the move to a RISC-type architecture doesn't make existing software obsolete. When it announced its new Spectrum line of minicomputers in February, HP went to great lengths to stress the line's compatibility with the company's older products. Calling Spectrum "the most ambitious development project Hewlett-Packard has ever undertaken," president John Young characterized the new computers as extensions, not replacements, to the company's commercial and technical product lines. HP, unlike most other vendors to date, is bringing RISC technology to bear on business applications as well as scientific and engineering tasks.

Several companies, including Ridge Computers (Santa Clara, Cal.), Pyramid Technology (Mountain View, Cal.), and Harris (Fort Lauderdale, Fla.), are already producing RISC-based minicomputers claimed to be more powerful and less expensive than Digital Equipment's popular VAX minis. Other companies, such as Mentor Graphics (Beaverton, Ore.) and Convex Computer (Richardson, Tex.), are making RISC coprocessors or other add-on components to improve performance of conventional computers and workstations. Still other firms, including Novix and MIPS, both of Mountain View, are producing RISC microprocessor chips that are claimed to be much more powerful than conventional CISC designs.

Machines with reduced instruction sets could be faster and less costly

RISC evolution. The aim of RISC design is to achieve the perfect balance between hardware-based and software-based functions to make each program run faster and more efficiently. But the label "reduced instruction set computer" says both more and less than it means: more, because a reduced instruction set is only one of several RISC design principles; less, because none of the new computers touted as RISC machines are pure examples of those principles (see "Defining RISC," p. 30).

RISC evolved from two fundamental developments: a better understanding of what actually happens when a computer executes a program, and the availability of "optimizing" com-

ILLUSTRATION BY VIRGINIA PECK

Defining RISC

Although the term "RISC" is sometimes applied to computers that simply have a small number of instructions, the RISC design philosophy really embraces six principles:

• ***Reliance on optimizing compilers.*** Almost all machine language code is generated by compilers that translate programs written in higher-level languages. Optimizing compilers not only translate the code but also restructure it so that it runs as efficiently as possible. RISC machines are designed to take advantage of this feature. The limited number and simplicity of their instructions reduces the number of options an optimizing compiler must consider when translating and rearranging a program.

• ***Few instruction and addressing modes.*** RISC reduces not only the number of instructions but also the number of ways of finding something in memory. The more complex CISC computers may have 15 or 20 different ways of locating data or instructions, and some addressing modes are quite slow because they involve considerable calculation; what's more, having numerous addressing modes greatly complicates compiler design. By contrast, RISC computers have only a few, very fast addressing modes.

• ***Fixed instruction format.*** Because conventional computer instruction sets are so large and complex, CISC instructions vary in length. Longer instructions require more time to decode, and compilers work slower when they must juggle the allocation of storage space for instructions of different lengths. RISC instructions are typically of uniform length.

• ***Instructions execute in one machine cycle.*** Unlike CISC designs, where an instruction may stretch over several cycles, RISC instructions take only one cycle. Not only is this faster, but it eliminates a lot of subordinate complexity since the compiler doesn't have to consider variable instruction times. The trade-off is that some very important kinds of instructions simply can't be done in one cycle—notably floating-point arithmetic and automatically loading the next needed program or data segment into memory from mass storage (virtual memory). General-purpose RISC computers get around these limits either by adding multiple-cycle instructions for such tasks or by having non-RISC coprocessors to do them.

• ***Only call/return instructions can access memory.*** Memory access is one of the biggest bottlenecks in software. By having just two instructions for that job, computer designers can concentrate on making them as efficient as possible. Limiting memory access also simplifies things for the compiler designer since no other instructions have to be checked for memory access before they execute.

• ***Hardwired control.*** CISC computers make extensive use of microcode for their instruction sets. Microcoded instructions are roughly equivalent to small computer programs, stored in special high-speed memory on the processor, that must be decoded by on-processor logic before being executed. Microcode allows large instruction sets (because each instruction is actually built up from a series of micro-instructions) and makes it easy to add or modify instructions fairly late in the design cycle, but it slows down the processor somewhat and requires that it be more complex. By contrast, RISC computer instructions are hardwired into the computer and act directly on the processor without having to be decoded first. This makes them faster and, more important, reduces the size and complexity of the processor.

pilers. When these compilers translate code from high-level languages such as C or COBOL into machine instructions, they also restructure the code so that it runs as quickly as possible, making the best use of the available machine resources. Standard compilers simply do direct conversion of the code, blindly translating line by line from the high-level language into the corresponding machine language.

About 10 years ago, computer scientists at IBM, Stanford University, the University of California at Berkeley, and other laboratories developed ways to observe what happened as a computer program ran. By running software emulations of hardware fuctions, and by directly measuring the internal states of operating computers, they gained a better understanding of what computers actually do—as distinct from what their designers thought they were doing. Hewlett-Packard also spent months analyzing the inner workings of its computers to gain a solid technical foundation on which to base its computer design. In all, literally billions of lines of computer code were analyzed.

Designers had assumed that the time a computer spent on a particular instruction was proportional to the number of times the instruction occurred in a typical program. So they concentrated on making the most common instructions run the fastest.

Another conventional practice was to provide a wide variety of instructions, each specialized to a particular task. For example, a typical CISC computer might have a dozen or more instructions for moving data—depending on such factors as the source, the destination, and the distance moved—and hundreds of instructions in total. For instance, the VAX has more than 300 instructions.

But it turned out that the time spent on each instruction was not directly related to the number of times it appeared in the program. For example, call/return instructions, which move parts of the program between memory and the central processing unit (CPU), accounted for only about 12% of the instructions in the average program, but they could take nearly 45% of the execution time.

To minimize call/returns and other time-consuming CPU/memory swaps, it made sense to increase the number of registers—the small pieces of random-access memory (RAM) in the CPU that hold instructions and data the computer is actively using. If the instructions and data aren't in a register, the CPU must first load them into one from its central memory—a process that takes two to 10 times as long as register-to-register operations. Pyramid thus built its minicomputer with 528 registers (conventional computers have fewer than 20). In effect, those extra registers serve as very-high-speed storage for active data and instructions.

Designing a computer with a lot of registers meant increasing the size of the CPU or making some other trade-off. What seemed to work best was to sacrifice much of the traditionally complex instruction set. This appeared to be desirable in its own right, since the analysis of programs being run indicated that a multitude of complex instructions didn't necessarily speed things up. Some complex instructions actually executed more slowly than equivalent sequences of simpler instructions. For instance, the VAX instruction for terminating a DO loop—a common programming operation—was slower than the three simple instructions it replaced. IBM researchers also found that some 20% of the instruction set was used about 80% of the time, and that some instructions were almost never used.

On close study, even some instructions that appeared to be fundamental turned out to be dispensable. HP's Spec-

RON KIMBALL

"It turns out that reduced instruction set computing is really a philosophical approach as much as an architecture. To many implementers, RISC is just common sense, and it would be nice to go back and call it 'common sense computer design.' "

**Rob Ragan-Kelly, Vice-President
Computer Architecture and Planning
Pyramid Technology**

trum goes so far as to do away with the "multiply" instruction. Multiplies take a lot of time, especially if they are performed by software, so designers always assumed that a hardware-based multiply instruction was required. But when HP's engineers examined the way multiplication occurred, they discovered that in most instances the multiplier was a fairly small integer. In such cases, multiplications are actually done faster by combining two simple instructions—add and shift (which is the equivalent of multiplying by two)—than by using a complex multiply instruction embedded in the computer.

Another drawback to having a host of similar special-purpose instructions is that they present the new generation of optimizing compilers with too many options and possible side effects to evaluate as they rearrange a program's code. "If you limit the choices available to the compiler, the compile time is faster and the program is easier to optimize," says Rob Ragan-Kelley, vice-president of computer architecture and planning for Pyramid Technology. "In a RISC machine, an ADD instruction takes its operands [data] from registers. On a VAX running an ADD instruction, each operand can be stored in any one of 14 different forms, so with two operands the compiler has 14 times 14 things to check for."

Users obviously benefit if the compiler can structure a program's translated code in such a way that the program runs faster. But RISC technology serves manufacturers as well. The time and money needed to design a new computer are closely related to the complexity of the instruction set: The more instructions, the more hardware logic is needed to implement and support them. Because RISC processors are much simpler than equivalent CISC units, they are easier to design and less expensive to build.

Still, RISC machines can add to certain aspects of hardware complexity—for example, in the form of hundreds of registers added to Pyramid's minicomputer. But even with these registers, Pyramid maintains that its computer is comparatively simple: Its CPU fits on four printed-circuit boards instead of the 19 needed for a VAX-11/780. The company also claims that its mini is 1.5 to 2.5 times as fast as the VAX.

Staying compatible. Despite RISC's apparent attractions, established computer firms with large bases of installed machines have trouble migrating to RISC designs. In doing so, they run the danger of stranding their existing customers with large investments in software that might not run on the new machines. Not surprisingly, then, start-up companies that lack such bases have been the first to produce RISC computers.

IBM largely sidestepped the compatibility issue; its RT/PC engineering workstation is competing in a market not previously served by the company. The RT/PC, which employs a 32-bit proprietary RISC microprocessor and an IBM-developed version of Unix, competes head to head with the established workstation products sold by Digital Equipment, Apollo Computer, and Sun Microsystems. Even so, IBM's use of Unix and its provision of a PC/AT-compatible coprocessing card are designed to make it relatively easy to translate existing software for use on the machine.

In Hewlett-Packard's case, the need to ensure complete compatibility with its earlier line of commercial and technical minicomputers was the most pressing aspect of its Spectrum development project. The HP 3000 had been extremely popular—with about 25,000 installations, the commercial minicomputer is second in numbers only to the IBM System 36/38 series—but its 16-bit architecture had been growing increasingly obsolescent. Also, the HP 3000 wasn't compatible with the company's other computers, built for engineering and factory automation applications.

In August 1982, HP canceled its plans for a conventional CISC replacement for the HP 3000 series in favor of what it calls "precision architecture." HP doesn't promote this design as a RISC architecture, since it includes many features that go beyond basic RISC principles. But the company acknowledges that an important aspect of the Spectrum line was the reduction and simplification of the HP 3000 instruction set. HP will also offer Spectrum machines designed to run the engineering and factory automation applications currently addressed by its 9000 and 1000 series.

To provide a software link with its existing base, HP's Spectrum computers will offer two levels of compatibility with the HP 3000. Using a special emulation mode, they will be able to run unmodified HP 3000 application software at about the same speed as the older machines. To exploit the increased power of the RISC-type architecture, users will employ an optimizing compiler to automatically recompile their existing application software. The programs will then run twice as fast as they did on the earlier HP machines, according to the company. The first two commercial Spectrum products—called the 3000 Series 930 and 950, to emphasize the relationship to the older designs—will become available in late 1986 and mid-1987.

The Spectrum name also reflects another advantage claimed for RISC machines: The same software can run efficiently on everything from personal computers to mainframes. Because a RISC computer, by definition, has a limited number of instructions, even small computers can hold the complete instruction set. A small machine won't run programs as quickly as a mainframe, and programs will have to be recompiled because of the inevitable hardware differences between the computers, but the software will run.

Opposing views. Not everyone is convinced of RISC's promise. The most vocal criticism has come from computer scientists in academia (as has the most vociferous support). CISC manufacturers have generally maintained a discrete silence about RISC concepts, saying only that RISC machines have yet to prove themselves in the real world.

Some computer architects see RISC as little more than a fad, and a misleading one at that. They assert that many of the claimed advantages of RISC have nothing to do with reduced instruction sets. For example, studies of RISC chips developed by David A. Patterson, the professor of electrical engineering at UC Berkeley who coined the terms "RISC" and "CISC," have shown that much of their performance derived not from having few instructions but from having a lot of registers. These same critics also note that RISC designs need to keep juggling program requirements with the number of available registers. If those factors get out of balance, the processor has to do a lot of time-consuming memory swaps, negating much of the performance advantage.

However, large numbers of registers aren't necessarily a requirement of RISC-based computers. Hewlett-Packard, for example, uses only 32 registers in its Spectrum machines. HP chose that number "based on a tremendous amount of analysis and simulation," says Tony Lukes, R&D manager at the Information Technology Lab. That HP was able to achieve optimal performance with so few registers refutes the argument that most RISC benefits accrue from the presence of large numbers of these storage components, Lukes believes.

RISC detractors also claim that the technology is unsuited to some of the jobs commonly required of modern general-purpose computers. For example, virtually every vendor of such machines offers so-called floating-point arithmetic capability for highly precise numerical calculations. And because

> *"The debate about RISC is really going to be settled by the machines that get built, as opposed to people agreeing on one philosophy or another. If it's a good idea, the RISC machines are going to be successful in the marketplace."*
>
> **David Patterson**
> **Professor of Computer Science**
> **University of California, Berkeley**

> *"There is no extremely sharp and theoretical demarcation in computer design that would put an architecture into the RISC or CISC camp. Any computer implementation is just one point in a design continuum."*
>
> **Joel S. Birnbaum**
> **Vice-President and Director**
> **Hewlett-Packard Laboratories**

ANDRE ABECASSIS

GEORGE STEINMETZ

floating-point operations require more than one machine cycle to execute, they don't fit easily into the single-cycle-per-instruction RISC philosophy. Similarly, it's very difficult to perform memory managment, or to swap chunks of data or programs between mass storage devices like disk drives and the CPU's memory, with combinations of simple instructions.

As a result, none of the general-purpose computers built with RISC principles are completely RISC machines. Rather, they are RISC-*like*. Most of them include at least a few complex instructions as well as instructions that take more than one machine cycle. HP's Spectrum series has about 140 instructions, for example, and Pyramid's computer has about 160. "Pure" RISC machines, such as some experimental

Computer makers gamble on RISC

Reduced instruction set computing (RISC) promises a new generation of faster and cheaper machines. The initial application of RISC principles has been in desktop workstations and minicomputers aimed at the fast-growing scientific and technical computing market. This market is currently worth $8 billion, and sales could leap to $28 billion by 1989, according to Harold Feeney, director of the technical computer systems industry service at Dataquest (San Jose, Cal.), a market research firm.

The major RISC vendors are Pyramid Technology (Mountain View, Cal.), a manufacturer of Unix-based superminicomputers; and Ridge Computers (Santa Clara, Cal.), a producer of computers for engineering workstations. Other companies entering the market include Harris Computer Systems (Fort Lauderdale, Fla.), an established minicomputer firm that has announced a RISC-like mini called the HCX-7; Convex Computer (Richardson, Tex.), a firm that uses RISC principles in its scientific superminicomputers; and Mentor Graphics (Beaverton, Ore.), which has announced a RISC-based graphics coprocessor to speed up its graphics workstations.

> ***"We think that current conventionally designed machines are like dinosaurs. Our new Spectrum architecture is intended to take this company's product line into the next century."***
>
> ***Edward Hayes***
> ***Marketing Manager***
> ***Information Technology Group***
> ***Hewlett-Packard***

Several companies are developing RISC microprocessors. Novix (Mountain View, Cal.) is shipping such a product, that runs the Forth high-level language, along with a development system that can plug into an IBM PC. Acorn Computers, a British microcomputer manufacturer, has developed a 32-bit RISC processor. And MIPS Computer Systems (Mountain View, Cal.) is developing a RISC microprocessor to speed up conventional workstations.

Two computer giants have also recently cast their nets into RISC waters. IBM (Armonk, N.Y.) has introduced the RT PC, a RISC-based workstation, in a move widely seen as supporting the commercial validity of RISC applications. Hewlett-Packard (Palo Alto, Cal.) is betting its $2-billion-a-year computer business on a series of RISC computers known as Spectrum, planned to replace its obsolescent minicomputer line. The company knows it is taking a gamble with such a bold move, but "all the Spectrum machines can run the same software our customers are now using," says Edward Hayes, marketing manager for Hewlett-Packard's information technology group.

RISC machines from smaller companies generally face an uphill battle in the marketplace. The main problem is competition from established minicomputer manufacturers such as Digital Equipment (Maynard, Mass.), Prime Computer (Natick, Mass.), and Data General (Westboro, Mass.), all of which offer similar non-RISC products and an established software base that may not run on the new machines.

To convince potential customers to make the switch, RISC machines must be clearly superior to the leading conventional machines. Even then, a new model from a major competitor can destroy any such advantage overnight. For example, "the only two general-purpose RISC machines now being produced are from Ridge and Pyramid," says Thomas Henkel, a senior market analyst at The Yankee Group (Boston), a market research firm. "For now, DEC has managed to more or less equal both of them with its new 8600 and 8650 and the MicroVAX II." But Edward W. Dolinar, chairman of Pyramid, contends that "the simplicity of RISC architecture enables us to match the efforts of the big companies to maintain whatever lead we need." He promises a more advanced RISC machine from Pyramid by midyear to match DEC's offerings.

Beyond the scientific and technical market lies the wider world of business applications. But most observers say that introducing RISC devices to commercial environments is problematic. Raw computing power is not as important a factor in this market as it is for the scientific market, and the Unix operating system of most RISC machines largely confines them to technical applications. Thus RISC penetration of the business market is likely to be gradual, depending on users' confidence in the reliability of RISC machines and the availability of compatible software.

> ***"RISC is a methodology, not a market. It will not, by itself, ensure the survival of RISC vendors; they must offer products with capabilities and applications that are significantly better than those of traditional computers."***
>
> ***Thomas Henkel***
> ***Senior Market Analyst***
> ***The Yankee Group***

Dataquest's Feeney believes that RISC-based computers will have to carry out a broader array of functions than pure-RISC machines to make their way in nontechnical markets. "In the long run," he says, "RISC principles will probably be integrated within the general computer market. At that point, we could see vendors mixing RISC architecture with some complex instructions and possibly floating-point and other types of coprocessors for specialized tasks."—***Rick Cook***

MARJORIE SIEGEL

units built by universities, employ only 30 or 40 instructions. But these machines have concentrated on executing instructions quickly—not on the overall speed of computing, having ignored jobs like input and output of data.

Another objection to RISC is its heavy reliance on compiler design. Without a good optimizing compiler, a RISC machine is considered no better than a CISC, and may very well be worse. But proponents reply that writing an optimizing compiler for a RISC machine is easier than it would be for an equivalent CISC machine, because of the inherent simplicity of RISC designs.

No one disputes, however, that RISC programs can be much longer than their CISC equivalents. Because the RISC instructions are simpler, more of them are needed to make up a program. The price of computer memory has fallen steadily, so this aspect is not as great a drawback as it once was. But computer memory is still limited, and programs cannot grow unbounded. If a RISC program is very much larger than a corresponding CISC program, it may be slower, because it will not all fit into memory at once.

Parallel competition. One of RISC's biggest problems may be that its speed improvements are minor compared with those theoretically possible through parallel processing. Of course, parallel computers have a long way to go before they fulfill their promise, and RISC proponents feel that the relatively straightforward RISC techniques can be brought to bear in the marketplace much more quickly. The comparison is pointless for another reason, they believe: RISC and parallel architectures aren't mutually exclusive. In fact, many parallel processing computers now being designed are decidedly RISC-like.

Some companies building parallel processors believe there are advantages to using RISC concepts, in that an optimizing compiler working on a simple instruction set can better handle the difficult job of dividing the work among multiple processors. One example of a parallel RISC processor is Mentor Graphics' Compute Engine, a coprocessor for Apollo workstations. "The compiler takes a normal C program and breaks it down into very primitive instructions like ADDs and memory operations that all programs have in common," explains Michael R. Butts, engineering manager of Mentor's Computer Systems Division. The compiler then allocates the simple instructions to the Compute Engine's different functional units, he says, which run them in parallel.

In the final analysis, many of its supporters believe RISC is simply an embodiment of the scientific and philosophic rule known as Occam's razor, which essentially states that among competing theories the simplest should be preferred to the more complex. "To many implementers," says Pyramid's Ragan-Kelley, "RISC is just common sense, and it would be nice to go back and call it 'common sense computer design.'"

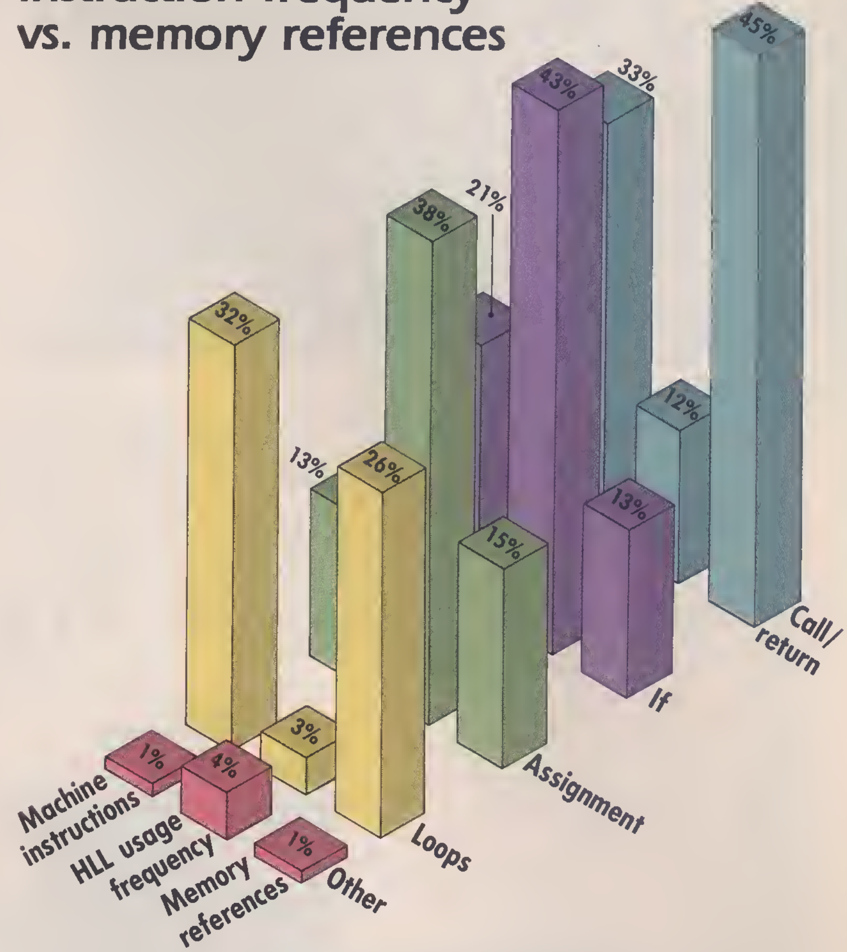
Some conclude that too much is made of the supposed dichotomy between RISC and CISC computers; manufacturers, they say, just want to devise the architecture that best meets the required performance and price goals. There is no "extremely sharp and theoretical demarcation in computer design that would put an architecture into one camp or the other," says Joel S. Birnbaum, vice-president and director of Hewlett-Packard Laboratories. "Any computer implementation is just one point in a design continuum, and the quality of the engineering trade-offs for any particular set of design goals always determines the results."

Still, the RISC backers believe their crusade will have a definite influence on the design of future computers. "RISC will eventually cause the dumping of some complex instructions that rarely get used," says David B. Folger, former president of Ridge Computers. "But it's not all black and white," he admits. "It's just a trend toward simplicity." □

Rick Cook is a freelance technology writer based in Phoenix.

For further information see **RESOURCES**, *p. 69.*

Instruction frequency vs. memory references



Analysis revealed that instructions appearing infrequently in high-level language (HLL) programs sometimes accounted for a much higher percentage of the code when the HLL was translated into machine language; they also used up considerable computer time, as measured by memory references. For example, call/return instructions constituted just 12% of a typical C program but accounted for 33% of the resulting machine instructions and 45% of the memory references. As a result, RISC processors were built to speed up instructions such as call/returns, even if it meant slowing the execution of less frequent operations.

SOURCE: DAVID A. PATTERSON & CARLO H. SEQUIN/IEEE COMPUTER, 9/82

The signs of change.

If you've been to The Californias lately, you know there's a new momentum, a new attitude that has made change a part of public policy and public policy a part of change.

Yes, The Californias comprise the world's seventh largest economy. And, yes, we may be the fourth largest by the year 2000. But it won't be because we're lucky or nice. It will be because we made it happen.

We're taking care of business. We're making it easier.

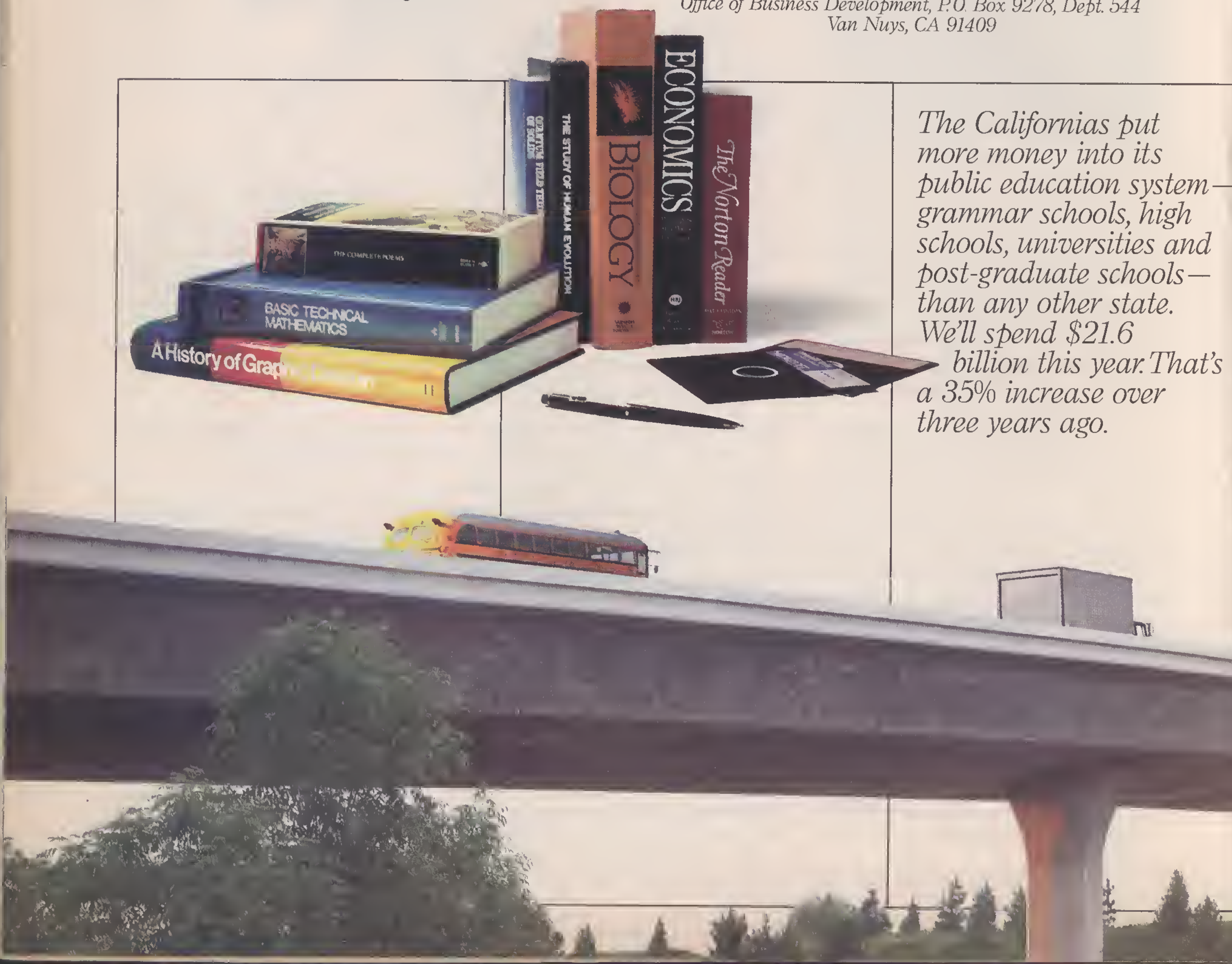
Maybe that's why nearly thirteen hundred companies have located or expanded here in the last three years.

The signs are everywhere, and they all say the same thing.

They all say "Go."

The Californias

California Department of Commerce
Office of Business Development, P.O. Box 9278, Dept. 544
Van Nuys, CA 91409



The Californias put more money into its public education system—grammar schools, high schools, universities and post-graduate schools—than any other state. We'll spend $21.6 billion this year. That's a 35% increase over three years ago.

Californians bought more retail goods in 1985 than Texas, Arkansas, Louisiana, and Oklahoma. Combined. Over $160 billion. (That's up 40% from 1980.) The state's total personal income for 1986 is forecast to grow 20% faster than the rest of the nation.

It takes a real leader to say this: The Californias are #23. In overall tax burden. In 1978, we were #4. We had a billion and a half dollar deficit in 1982. Now we have almost a billion dollar surplus. Without a general tax increase.

The Californias have seen nearly $35 billion of new commercial and industrial construction since 1980. But we still have all the land you need, at every price—including more fully-improved business parks than anywhere else in the world.

The Californias will spend $3 billion on streets, sewers, water delivery and related infrastructure this year. That's 1/3 more than 1984. (And an additional $16 billion expenditure before 1990 has been proposed.)

If you've priced office space in London, Tokyo or New York lately, $50 per square foot per year won't surprise you. Compare that with a ringside seat on The Pacific Rim for just $26 or $30 in Los Angeles or San Francisco.

Circle No. 16 on Reader Service Card.

RETHINKING SPACE BUSINESS

by Peter Gwynne

The loss of the Space Shuttle *Challenger* and its crew last January brought American space-commercialization efforts to an abrupt halt. But even before that, U.S. business was moving into space less rapidly than many analysts had anticipated. Delays in launches, huge insurance claims, and difficulties in obtaining capital had slowed down several projects on the way to the launchpad. The current hiatus in shuttle launches certainly exacerbates those problems, but it also gives government and business planners the opportunity to reassess the nation's space-commercialization policy. The task ahead of them is to ensure U.S. leadership in space despite fierce foreign competition.

Several other nations are aggressively preparing to serve the markets of the next decade. A consortium of European countries has captured a significant proportion of the available launch business. Japan, the Soviet Union, and even China are threatening to follow. Great Britain intends to build a space plane, and France has plans for a mini-shuttle. The French might also monopolize remote sensing over the short term. A group led by the West Germans has recently formed a company to make commercial use of the microgravity environment of space; in fact, more than half the orbital tests on materials processing carried out so far have been non-American.

The U.S. has not stood still commercially. For example, NASA offers companies low-cost launches for their payloads. And the agency's new Office of Commercial Programs has set up five centers for commercial development, to provide the knowledge bases necessary for eventual commercialization of such areas as remote sensing and materials processing. The model for these efforts, according to Isaac Gillam, head of the office, is communications satellites, which started life as a government program and developed 20 years ago into a major industry. The industry blossomed because there was a clearly defined market, an appropriate space infrastructure, and government determination, through the Communications Satellite Act, to shift the endeavor to the private sector. "The key element in these activities," says Madeline Johnson, Director of the Office of Commercial Space Transportation Programs at the Department of Transportation, "is that when the profit motive was introduced, innovation to bring the cost down began to show itself."

A major objective in the wake of the *Challenger* disaster is to determine the number and type of launch vehicles that will best achieve commercial competitiveness. NASA has already announced that it will turn from exclusive use of the Space Shuttle to a combination of shuttle orbiters and expendable launch vehicles (ELVs). But the actual composition and administration of this mixed fleet will depend heavily on anticipated demand.

Europe's Ariane, the main rival of the U.S. in the launch business, has consistently undercut shuttle prices.

Uncertain markets. Military and scientific needs will take precedence when the three-orbiter shuttle fleet resumes flying, according to NASA's tentative schedule. A study by General Dynamics' Space Systems Division (San Diego) identifies 19 priority Defense Department missions on the current shuttle manifest. A dozen large scientific payloads, such as the Ulysses mission to Jupiter, the Hubble space telescope, and the European Spacelab, should also gain early access to the shuttle; they need either the lifting power or the human handling that only the shuttle can provide.

Even assuming the best case—a restart next February at a

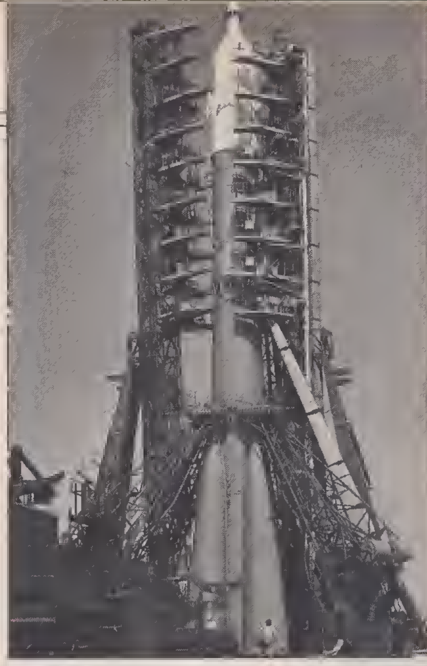
Out of adversity may come new U.S. strategies for commercializing space and meeting foreign competition

GENERAL DYNAMICS

The Atlas-Centaur (above) and the Delta (below) could form the nucleus of a U.S. commercial launch industry. Both expendable launchers have built up impressive records of reliability during several years of orbiting payloads for NASA and the Air Force.

McDONNELL DOUGLAS

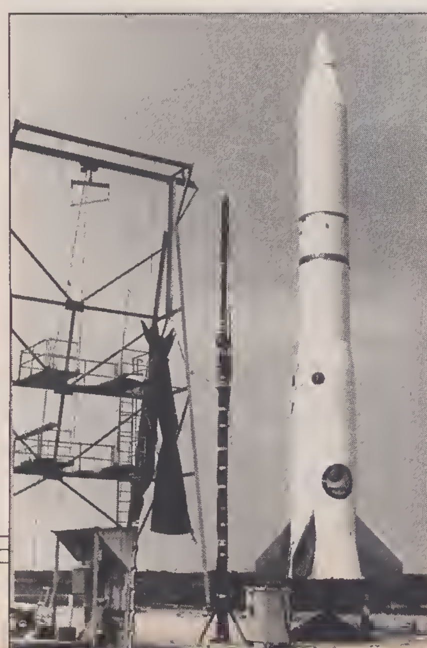
Right: Space Services' Conestoga is a true commercial launch vehicle, built from off-the-shelf parts without government backing. Despite a successful suborbital test flight, the craft has not yet attracted any customers.



INTERFOTO MTI & HUNGARY

© 1986 SIGNAL

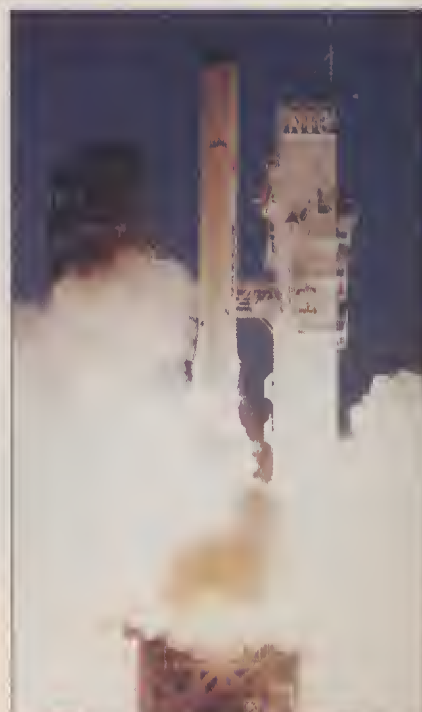
Top: The USSR is seeking commercial payloads to launch from its facility at Baykonur. Above: The Chinese, meanwhile, are promoting their Long March rockets.



SPACE SERVICES

MARTIN MARIETTA

Above: The Titan 34D is the latest version of the expendable launcher that lofted most large Air Force payloads into orbit before the Space Shuttle. A new batch of Titans will complement shuttle launches for the Air Force starting in 1988.



NASDA

Above: Japan plans to enter the global launching market in the early 1990s. Its commercial vehicle will be the two-stage H-II rocket, an upgraded version of the N-II (shown) that will be built entirely in Japan.

rate of 11 flights per year—these priority missions alone would book up the shuttle until the end of 1989. Thus, because "commercial satellites, along with smaller government satellites, will not be flown in this period," says Lee R. Scherer, director of commercial space for General Dynamics, they will be candidates for U.S. ELVs.

Commercial satellites—for communications and remote sensing—can be orbited adequately on throwaway launchers. The European Ariane system has lofted 17 communications satellites, and American ELVs such as the Delta and Atlas-Centaur have orbited more than 90. The advantages of ELVs for commercial satellites, says C. J. Waylan, president of GTE Spacenet (McLean, Va.), "include lower cost, simpler design, and less complex deployment techniques."

PETER VIDOR

Some U.S. corporations, such as 3M, are preparing for commercial space ventures by undertaking ground-based R&D (top). Once in orbit, they will face tough competition from foreign companies, warns Geostar's Gerard O'Neill (bottom).

But the area of greatest commercial activity, communications, is becoming saturated. At present, about 20 commercial communications satellites go into orbit each year. That amount of traffic—a significant increase over the rate of the early 1980s—is clogging up the most desirable slots in geosynchronous orbit. In addition, the most modern satellites have the reliability and the fuel capacity to last for 10 or more years, rather than 4–5 years as before. Replacements for dead or obsolete satellites, along with new satellites to fulfill specialized needs such as mobile communications, will guarantee high demand for launchers for the rest of the decade, says Jack Frohbeiter, vice-president and general manager of RCA Astroelectronics (Princeton, N.J.). But after that, he says, the situation becomes less predictable.

Commercialization of remote sensing, the next great hope for space-based profits, "is somewhere between infancy and adolescence," says Frederick Henderson, president of the Geosat Committee (San Fancisco). NASA's Landsat series of spacecraft—which generated $18 million last year, largely from mineral and agricultural surveys—was privatized in September as the Earth Observation Satellite Company (EOSAT). In February, the French company SPOT Image joined EOSAT in the commercial market when its SPOT 1 satellite reached orbit aboard an Ariane 1 booster. But few fresh launches are in the offing. Because of haggling over a decision by the Office of Management and Budget to delete from the fiscal 1987 budget a payment of $94 million to EOSAT for operating Landsat, the launch of the next Landsat orbiter could be delayed from 1988 to 1990, possibly leaving SPOT 1 as the only collector of remote images by late in the decade.

Further progress in commercial remote sensing will depend on improved technology and the evolution of markets for the data that the technology provides. Potential customers will take about a decade to understand how best to use satellite data, says Charles Sheffield, vice-president and director of special projects for Earth Satellite Corp. (Chevy Chase, Md.). Meanwhile, he contends, image resolution is improving so rapidly that, by the year 2000, satellites will compete directly with aircraft in collecting data.

But Sheffield sees one practical problem: Satellites will far outlast the technology aboard them; to remain at the state of the art, they will need periodic upgrading. "It seems likely," he says, "that before the end of the century a multitude of unmanned platforms will be in orbit," each fitted with modular components and served by the Space Shuttle or its descendants.

Materials processing is the space business that analysts consider potentially the most important, but its time has not yet come. Within the past year, two prospective partners pulled out of a pioneering orbital venture with McDonnell Douglas Astronautics (St. Louis) to grow a very pure form of erythropoietin, a hormone that stimulates production of red blood cells. However, several companies, including 3M (St Paul, Minn.), Deere & Co. (East Moline, Ill.), and Microgravity Research Associates (Coral Gables, Fla.), are preparing for commercial ventures by doing R&D in space or in earthbound laboratories. Predicting the demand for ELV launch services in this area is difficult, though, because materials-procesing payloads will often require the tender loving care that only astronauts can give.

Regardless of their specialty, space manufacturing entrepreneurs have had trouble obtaining financial backing. "They're going into a hard-to-reach environment to make products whose uniqueness they can't guarantee," says Wolfgang Demisch, aerospace analyst at First Boston (New York). And, he notes, the capital requirements are prodigious: "In space, you can't start small and grow."

Moreover, recent losses by space ventures have done little to encourage investors in orbital enterprises. Two direct broadcast satellite companies, United Satellite Communications and Satellite Television Corp., each lost more than $50 million within about two years. Remote sensing ventures Space America and Sparx fell $2 million and $1 million into the red.

Price wars. The uncertain speed of development for different space business sectors and the difficulty of obtaining capital are just two of the major problems faced by planners determining future U.S. launch capacity. Another is the impact of overseas government-financed launch companies.

Arianespace, the French launch company, has consistently undercut shuttle prices. "They have made some very sweet deals with American companies to get them to commit to several launches," reports Gerard O'Neill, president of the radio navigation company Geostar (Princeton, N.J.).

Half a world away, China's Great Wall Missile Company (Beijing) seems determined to become the Crazy Eddie of the launch business, promising to better any price offered by rivals for launching and insurance. "This gives the Chinese the opportunity to earn hard currency, and they're going after it very aggressively," says S. Neil Hosenball, a former general counsel of NASA who is now director of the Center for Space Law, Business, and Policy at the University of Colorado. "It's a serious threat" to commercial U.S. launchers.

In response, NASA has joined the discount business, offering cut-rate prices for commercial shuttle payloads. Before *Challenger*'s demise, the agency charged about $25 million for launching a commercial satellite. Launching three satellites per shuttle mission, NASA collected perhaps $175 million less than the actual cost of getting the cargo into orbit. Ariane's charges are similar, but the unmanned vehicle's overhead is significantly lower.

The U.S. government must take a major share of the blame for the rapid emergence of foreign launch competition, according to such observers as Geostar's O'Neill and former Secretary of the Air Force and NASA deputy administrator Robert Seamans, now a lecturer at MIT. The stimulus was its decision in 1972 to use the Space Shuttle as the sole U.S. government launch system—for communications satellites and passive scientific studies (which did not need its unique capabilities), as well as for military payloads and materials-processing experiments (which did). "There has always been a feeling in Europe that you need a stable of launch vehicles—a mixture of the shuttle and expendable launch vehicles, of manned and unmanned," says Ian Pryke, head of the Washington office of the European Space Agency (ESA). "The emphasis on the shuttle was not the thing for the U.S. to do."

But that emphasis seemed unavoidable, given the political history of the shuttle. In the late 1960s, NASA asked for a $10 billion fully reusable orbiter, to be developed as a first step toward a manned space station, manned planetary missions, and a manned moon base for extracting lunar minerals. The agency had not reckoned on the weakness of the U.S. economy or on national disillusionment with large technological projects. The Office of Management and Budget, reflecting public and congressional opinion, offered $5.5 billion, take it or leave it.

NASA took it, but there were strings attached. For one thing, the Air Force demanded a huge payload capability of 65,000 pounds and the ability to glide 1100 miles to either side of its orbiting path on returning to earth. For another, OMB limited NASA's annual expenditure on the project to about $1 billion. Those requirements severely boxed in the shuttle's design. "We built it to a political standard, not necessarily to an engineering standard," says Greg A. Mann, a former shuttle official who is now project director of the List Institute for the Strategic Exploration of Space (Colorado Springs).

The result was a Space Shuttle that nobody really liked. It was only partly reusable. It was expensive to run. And it lacked the redundancy in design necessary for fast technical fixes of the problems that inevitably appear during development. Plans for an initial orbital flight in March 1978 collapsed when the shuttle's heat-resistant tiles and main engines developed major difficulties (the first orbital flight was in April 1981). What's more, the intended schedule of 60 commercial flights per year by 1985 proved highly unrealistic.

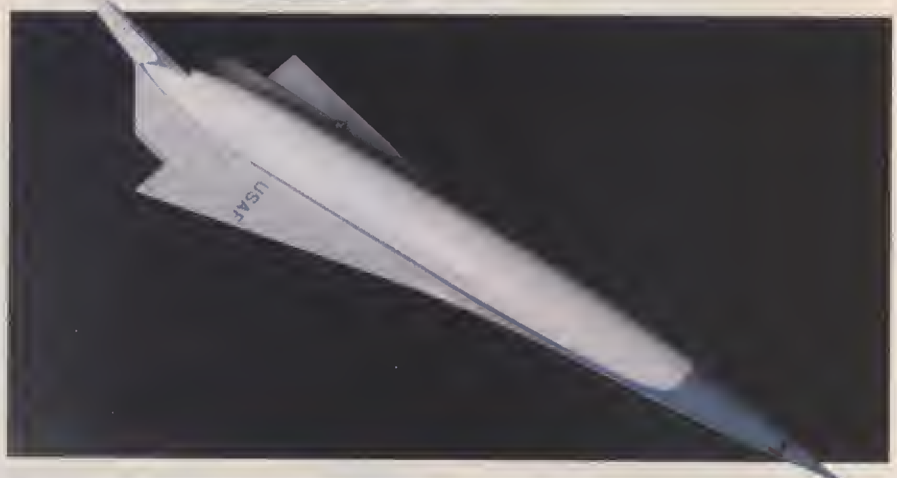
The delays worried the Air Force more than any other user. In the late 1970s, with its supply of ELVs running out, it urgently needed the shuttle in order to continue launching reconnaissance satellites to verify Soviet compliance with the Salt II treaty. That requirement convinced Congress to vote the funds necessary to complete the project fast. But it also put the shuttle program in thrall to the military, says space historian Alex Roland of Duke University, and because it meant reducing both the number and priority of commercial flights, it destroyed the initial promise that the shuttle would pay for itself through charges to customers.

Ironically, the shuttle didn't fully satisfy the Air Force. Officials were concerned about vulnerable "single threads" such as the specially adapted Boeing 747 that transports shuttle orbiters from California to Cape Canaveral; if the transport plane broke down, they reasoned, all shuttle flights would be frozen for several months. As a result, they started to lobby for fresh ELVs in the early 1980s. "It didn't make sense to us to absolutely rely on four orbiters," says MIT's Seamans, who headed an Air Force panel on launch capabilities.

Last year, Congress granted the service permission to order 10 Titan 34D-7s (the latest versions of the expendable workhorses that lifted most heavy Air Force payloads before the shuttle) for delivery starting in 1988. Since the

The Space Shuttle's capabilities far exceed those of expendable launch vehicles. But high costs make it vulnerable to competition from ELVs.

Vehicles now on the drawing board in three spacefaring nations will vie for space transportation business in the 1990s and beyond. The French Hermès (left), a small, specialized version of the Space Shuttle, will ferry two astronauts into orbit for maintenance and repair work. The U.S. space plane (below) is designed to orbit people and payloads at a tenth the current cost, and to carry passengers across the Pacific in less than two hours. Britain's HOTOL (bottom) will perform similar functions.



Challenger explosion, the Air Force has requested more. It also plans to upgrade the smaller Titan IIs, now being retired from service as intercontinental ballistic missile launchers, into Titan 34D-7s.

Because the Air Force order will claim the next several years' output of Titan 34Ds, only two tried-and-true rockets will be available for nonmilitary launches: General Dynamics' Atlas-Centaur, and McDonnell Douglas's Delta. The Atlas-Centaur can boost 4150 pounds into geostationary orbit, and has had a launch success rate of 97%. The Delta, which can loft 2850 pounds into an elliptical transfer orbit ready for final boost into geostationary position, boasts 43 straight successful launches. Far behind in power and experience is the Conestoga, an expendable launcher assembled from off-the-shelf parts by Space Services (Houston), which made a single suborbital test flight in 1982. The company has announced plans for vehicles capable of launching 300 to 3000 pounds into low earth orbit.

The Space Transportation Architecture Study, an interagency panel set up last September, is examining two expendable launchers with high boost power, according to NASA's chief of advanced transportation, Larry Edwards. One resembles the Space Shuttle's main engine, burning a mixture of liquid hydrogen and liquid oxygen. The other is fueled by liquid oxygen and a hydrocarbon such as methane or propane, which is much denser than hydrogen.

The panel is also considering an upgraded shuttle. Maxime Faget, formerly head of engineering at NASA's Johnson Space Center and now president of Space Industries (Houston), suggests two adaptations that could increase the system's payload capacity: improved main engines on the orbiter and extra engines attached to the external tank.

Meanwhile, Anthony J. Cipriano, chairman of the Space Commerce Roundtable Foundation (a group set up by New York–based financial and engineering societies interested in space commerce), has called for a program to attack a serious weakness in the present shuttle fleet: Because engineers routinely cannibalize freshly landed orbiters to obtain parts for orbiters on the pad, the fleet effectively consists of $2\frac{1}{2}$ working orbiters rather than three. Cipriano suggests that NASA beef up the orbiters' inventory of spare parts, in addition to ordering one or two more orbiters.

Commercial launching. Who should manage the newly ordered ELVs and shuttles? There are three basic options: NASA and the Air Force can resume their traditional roles as sole owners and managers of their mixed fleets; they can purchase complete launch services from commercial companies; or they can pursue a combination of the two approaches.

Two and a half years ago, the U.S. government put a cautious toe in the waters of launch privatization. An interagency group selected General Dynamics to market its Atlas-Centaur system, and chose Transpace Carriers (Lanham, Md.) as the franchise holder

The high cost of foul-ups

Despite President Reagan's July 1984 announcement that "we have cultivated space for the past 25 years, and now is the harvest time," space commercialization has lately been encountering a series of setbacks. The *Challenger* disaster was its most devastating reverse, but a continuing problem has been the inability of launchers, both manned and unmanned, to lift off on schedule and to deliver payloads reliably into orbit.

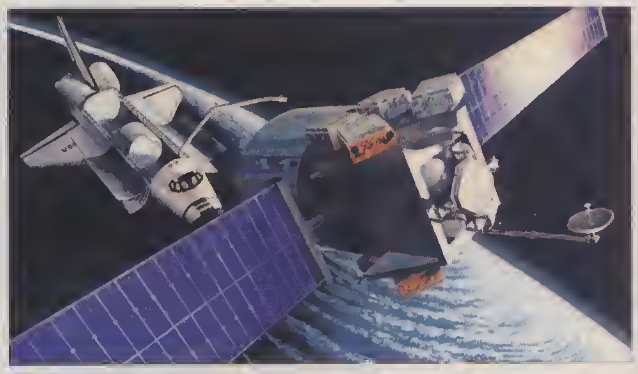
All last year, missions of the Space Shuttle suffered nagging delays owing to bad weather, computer glitches, and slow turnarounds. The *Columbia* mission immediately prior to the fatal *Challenger* flight, for example, had to put down in California instead of Florida because of three days of bad weather at the Kennedy Space Center. That threatened to delay the next *Columbia* mission, although the issue became moot. The European Ariane system has also experienced problems. A flight failure last September set back the next launch by three months. Computer malfunctions and anomalies in telemetry data caused three delays to the flight after that.

The lack of reliable launch dates does not make for good commercial planning, and there is scant prospect of improvement in the near future. Even when it restarts, the shuttle will take some years to work through its backlog, while Ariane's maximum frequency for the next few years is nine launches annually. What's more, alternative expendable launchers will not be available for at least two years.

Outright failures have severely harmed the young space insurance industry. In 1984 and 1985, seven communications satellites either did not reach orbit or malfunctioned once there. According to James W. Barrett, president of International Technology Underwriters (Washington, D.C.), insurance companies paid out about $632 million in damages, but collected only $194 million in premiums.

Underwriters now recognize that they set their premiums too low. Rates below 10% of payload value for coverage from launch to start-up in orbit just didn't reflect a realistic assessment of the risk of space launches, says Brian Stockwell, president of Corroon and Black Inspace (Washington, D.C.). But underwriters can adjust their rates only so far in the effort to recoup the losses. Rather than pay a 28½% premium for launch of its $80 million Ku2 satellite last November, RCA elected to launch self-insured—and won the bet when the satellite reached orbit in perfect condition. "That shook the industry," says Stockwell. "Now quotes are all over the place." Effectively, though, the most common rate is around 20%.

Even if they're willing to pay, satellite owners face a complication: Seeking to minimize losses, the underwriting community refuses to cover more than $100 million on a single risk—that is, one space launch. Since Ariane carries two satellites at a time—each worth up to $100 million—and the shuttle can hold three, it seems to be impossible to launch either craft fully loaded with insured commercial payloads. In response, Arianespace, the company that operates the Ariane boosters, has developed its own launch risk package. A premium of 11% ensures a free relaunch on Ariane in the event of launch failure, while a 13.2% premium buys a complete money-back guarantee.



Fairchild's Leascraft, a proposed orbiting platform for rent, fell victim to market realities.

The experience of Fairchild Space Company (Germantown, Md.) illustrates the problems that can plague the best-laid commercial space plans. Five years ago, the company developed the concept of an orbiting platform for long-duration experiments and manufacturing in space. The Leasecraft, as it was called, would be launched by the Space Shuttle and visited semiannually by shuttle astronauts for maintenance and for placement and removal of payloads. It had two potential customers. McDonnell Douglas Astronautics (St. Louis) was interested in using the platform to produce a hormone in a very pure form, and NASA talked about using the platform for its extreme ultraviolet explorer experiment.

But last year a series of problems combined to freeze the project. NASA refused to accept any termination liability—that is, to make up the difference in cost if commercial customers pulled out of the project while NASA remained. Fairchild could not persuade venture capitalists to finance more than a portion of the Leasecraft's costs. And since the company could not obtain adequate insurance coverage, it faced the risk of losing $60 million if the launch of the Leasecraft failed. Finally, McDonnell Douglas decided that it could produce commercial amounts of its hormone on short shuttle flights rather than long Leasecraft stays.

Today, Leasecraft lies in limbo. Fairchild continues to market the platform, but has no schedule for launching it without commercial customers. "Everybody had the best of intentions, and I can't find fault with anybody," says John Naugle, a one-time NASA official who was Fairchild's chairman and chief executive officer until last year. But the affair "lowered my outlook for the potential commercial market substantially."

---

for McDonnell Douglas's Delta rockets.

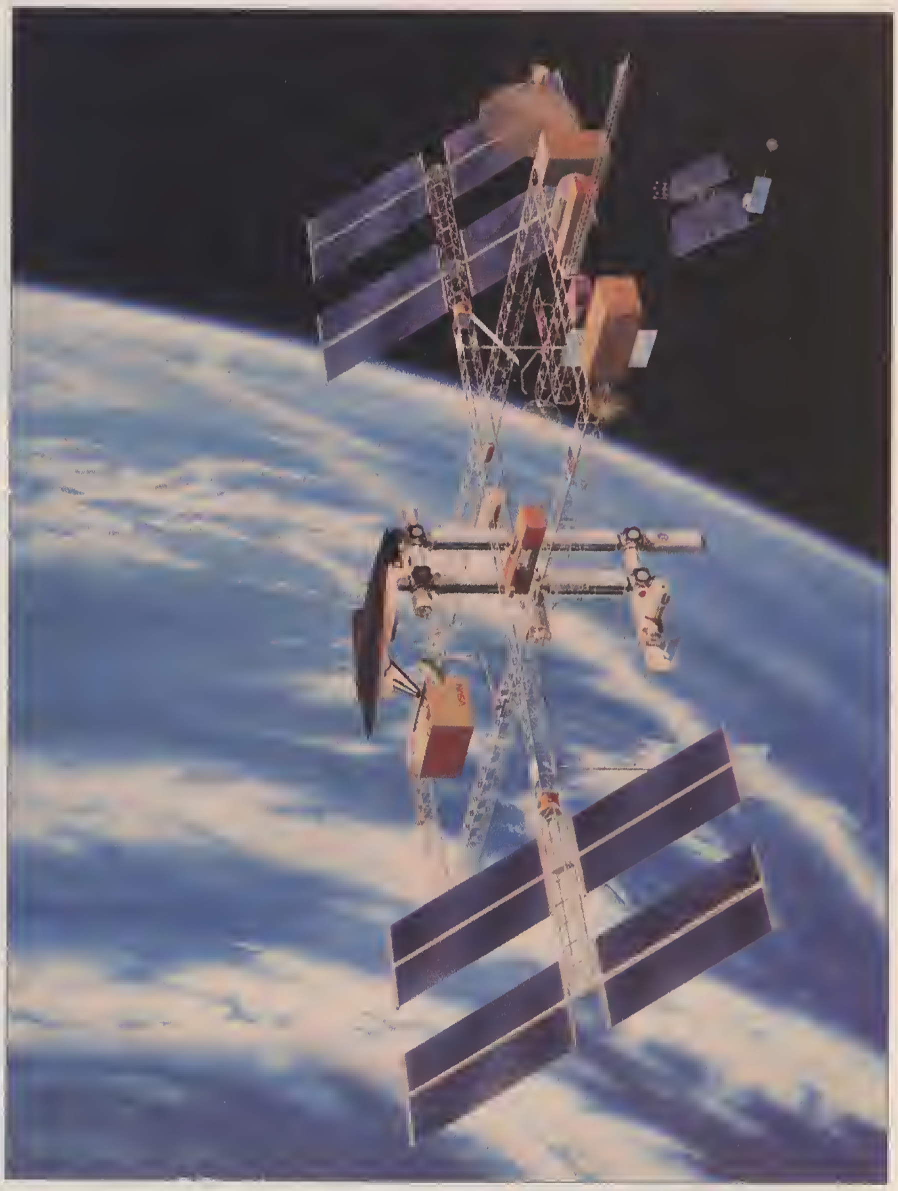
So far, however, commercial customers haven't beaten a path to the launchpad. Neither company has made a single sale, in fact. "Until the *Challenger* accident," says ESA's Pryke, "it looked as if American efforts to commercialize ELVs were going nowhere." A door for commercial ELV companies has plainly been opened, but the opening may still be too narrow to accommodate commercial launchers. One problem is payload compatibility. "We've been forced to work inside the shuttle envelope and capabilities," declares RCA's Frohbeiter. "I think the [communications satellite] industry would react in a very hostile manner" if it were banned entirely from the Space Shuttle. Even the small payloads that commercial rockets such as the Conestoga can handle have been uniformly adapted for the shuttle, complains former astronaut Donald K. (Deke) Slayton, who heads

Space Services. Payload owners are leery of the time and cost involved in readapting.

And of course the foreign threat won't go away. "It's going to be a very competitive environment on the international scene," says Arthur Manfredi, specialist in aerospace policy at the Library of Congress. Foreign competitors won't necessarily hew to the rules of free trade; John Logsdon, head of the graduate program in science, technology, and public policy at George Washington University, sees analogies with flag-carrying airlines, supported by their governments through rivers of red ink. "The approach of these quasipublic, quasiprivate organizations backed by government is something we can't do," he says.

The U.S. government can, however, provide its own specialized subsidies to boost the strength of a young commercial launch business. An existing program allows NASA to defer charges for launching entrepreneurial companies' payloads until the payloads start producing revenue. Geostar has already signed up for the program, and Space Industries plans to use it in orbiting its industrial space facility, a privately run astronaut-tended platform that will offer long-term exposure to the microgravity of space for experiments and commercial payloads. Analysts see no objections to extending the program to provide pay-later launchpad support for commercial launch companies.

Even a uniform NASA pricing policy could help. Alan M. Lovelace, vice-president and general manager of General Dynamics' Space Systems Division, has called on the space agency to reduce scheduling pressures by adopting a single set of prices for NASA-launched payloads, regardless of the launch vehicle used. And, says Lovelace, "the new price should be [high enough] to provide a basis for transition to commercial launch services" soon after NASA has satisfied customers on its current manifest.



Even in its early design stages, the U.S. space station has sparked controversy. The issue: Will the orbiting edifice really serve commercial ends?

The government could also help to convince the investment community of commercial launchers' viability by becoming a customer. Guaranteed government business, says Space Services' Slayton, will help the launch companies to raise capital. In fact, both NASA and the Air Force have suggested in congressional testimony that they will consider farming out some launches to the commercial sector. But Ray Williamson, a project director at the Office of Technology Assessment, warns that NASA's internal structure might impede such support. "Buying services goes against the culture of NASA," he argues.

A major barrier still to be overcome is insurance. Even though the Delta rockets have a flawless record, says the University of Colorado's Hosenball, franchise holder Transpace Carriers will probably find it tough to obtain insurance coverage, because the company has not launched any rockets on its own. One solution under study by the interagency panel on launch commercialization: Make the U.S. government the insurer of last resort.

Needed: government funding. Clearly, any commercial U.S. launch business—whether shuttle- or ELV-based—will initially need government support to compete with Ariane and other foreign, government-subsidized launch services. But Ariane presents a moving commercial target. Ariane 1, a three-stage ELV that can loft 4000 pounds into geostationary orbit and more than 10,000 pounds into low earth orbit, has been joined by Arianes 2 and 3, with more power and lower cost per pound of payload. In August, Ariane 4 will go into service, offering yet more capacity and flexibility. On the drawing board, with a target date of 1995, is Ariane 5, intended to offer a cost advantage of 20% over Ariane 4.

The French have designed an optional module for Ariane that will carry two

astronauts, with a minimum of extra payload, into orbit to tend satellites and experiments, and then glide back to earth. The squat craft known as Hermès is to the shuttle what a car is to a truck. "The shuttle is a multimission space vehicle that was designed to do everything," says Arianespace president Frédéric d'Allest. "Our approach is very different: We consider specialized systems to be more efficient than multipurpose systems."

China's Long March series of rockets, the only ones outside the U.S. with cryogenic stages (the most complex form of booster), can carry up to 3000 pounds into low earth orbit. According to Manfredi at the Library of Congress, the Chinese have started talks with Singapore on a joint venture to build a launch facility in Indonesia; such a facility, within a few degrees of the equator, would improve the Long March system's ability to launch payloads into geostationary orbits. In February, the Swedish Space Corporation announced that it had signed a preliminary agreement to use Long March 2 rockets to orbit its small Mailstar electronic mail satellites.

The Russians have offered to launch payloads on their Proton rocket at cut-rate prices of less than $25 million per satellite. According to the U. of Colorado's Hosenball, their almost-live television coverage (they ran with a one-minute tape delay) of the March blast-off that sent two cosmonauts to the newly lofted space station was an attempt to resolve Western misgivings about the openness of their program.

Few analysts doubt the validity of future launch competition from Japan. The first flight of the two-stage H-II rocket, built completely in Japan, is scheduled for 1992. "When H-II becomes operational, we shall be able to participate in all aspects of world space activities," says Hiroyuki Osawa, president of Japan's National Space Development Agency.

The competition won't end with rival stables of ELVs. The U.S. already faces a commercial challenge to its plans for the next generation of spacecraft. NASA and the Air Force have begun sponsoring a research program to develop a space plane that will soar into orbit from conventional runways. They envision not only a craft that will carry military and civilian astronauts and payloads into orbit for about a tenth the shuttle's cost per pound but also an "orient express" to fly passengers from the East Coast to Japan in two hours. Not to be outdone, the British have announced their own horizontal takeoff and landing craft (HOTOL), a single-stage, automatic, reusable craft that will take off from a trolley racing down a runway and cruise back to earth. HOTOL will have the power to place satellites into high orbit and ferry astronauts into space. Designers also promise a version that will carry passengers from London to Australia in slightly more than an hour.

The survival of these new projects depends critically on government support. The space plane demands continued funding from Congress, and HOTOL (and the French Hermès) will not be built unless the eleven members of the European Space Agency agree to pay development costs of several billion dollars. The U.S. clearly has the edge in developing the propulsion technology, advanced materials, and avionics systems that a space plane will need. The project "holds the key to regaining the substantial lead in aerospace once enjoyed by the United States," claims Roger D. Schaufele, vice-president of engineering at McDonnell Douglas's Douglas Aircraft Co. (Long Beach, Cal.). But critics such as John Pike, an analyst at the Federation of American Scientists, argue that the plane has no effective use beyond military payloads and that its promoters have underestimated the complexity and cost of the technology.

A similar divergence of opinion has occurred over the U.S. space station (HIGH TECHNOLGY, April 1985, p. 18). As planned, the 6-module, $8 billion station will consume a large percentage of shuttle flights and NASA funds in the early 1990s. While the station's nominal goal is commercial, observers such as Logsdon of George Washington U. wonder whether NASA will permit industry's needs to drive the station's technology rather than vice versa. Noting the complexity of current designs, Diana Josephson, director of marketing for Arianespace, expresses concern "that NASA is approaching the space station as an R&D project, not a potential business." However, Marc Vaucher, a program manager at the Center for Space Policy, Inc. (Cambridge, Mass.), argues that any new piece of technological infrastructure must have a significant R&D component. "It's absurd to say that you make it commercial from the start," he says.

NASA claims that the space station is integral to its vision of space as the scene of 21st-century commerce and international cooperation. But if the agency fails to emphasize commercial applications, foreign competitors may seize the initiative. The European Space Agency's Columbus module is designed as a materials-processing laboratory that can be tethered to the space station or flown freely in orbit, and some observers suspect that the Europeans might try to launch Columbus as a space station in its own right if the U.S. program is seriously delayed or not commercial enough. "The Europeans have plenty of ways to do end runs around the space station," says Geostar's O'Neill.

In a report completed this spring, the National Commission on Space foresees a space infrastructure that will reduce both the cost of reaching low earth orbit and the cost of proceeding from there to the moon, Mars, and the asteroids. It envisions industrial parks in orbit, where entrepreneurs will have all the facilities they need for manufacturing in microgravity. And it calls for manned and unmanned vehicles of the future to be developed in concert with industry, so that they can be taken over by the commercial sector when their technologies mature.

The exact path to that future will depend on a series of decisions, some to be made within the coming months, on the nature and administration of U.S. launch capabilities. Decision makers will plainly want to avoid repeating the mistakes of the shuttle program and formulate a truly effective policy for space commercialization. But first they must overcome some institutional biases: the temptation to push the technology without thought for the needs of potential users; the lure of serving as many constituencies as possible in order to guarantee maximum political support; and the desire to achieve everything as cheaply as possible (an especially pernicious influence in these days of Gramm-Rudman-Hollings).

These issues together pose a difficult challenge. Yet if the U.S. doesn't begin to confront them during the hiatus in space activity caused by the *Challenger* catastrophe, others will grasp the commercial opportunities. Then the launch vehicles, factories, and space settlements of the 21st century could be dominated by foreign companies, just as the driveways of well-to-do U.S. suburbs today are filled with BMWs, Volvos, and Mazdas. □

Peter Gwynne is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

SCIENCE/SCOPE®

Twenty years ago on June 1, Surveyor 1 made the first soft landing on the moon, giving scientists their first close-up look of the lunar surface and blazing a trail for the manned Apollo missions three years later. The three-legged spacecraft, built by Hughes Aircraft Company, landed one second ahead of the originally predicted time and just nine miles from the predicted target point after traveling 240,000 miles. In the following eight months, Surveyor televised 11,150 pictures, photographed the solar corona of the setting sun, made a color composite photo of the lunar surface, and measured the hardness of the lunar surface. By January 1968, four other Surveyors had made soft landings on the moon. They provided detailed scientific information about the physical and chemical character of lunar materials and added immeasurably to the understanding of the physical processes that shape the moon's surface.

The oldest continually operating communications satellite has been turned off after 19 years of service. The first Applications Technology Satellite (ATS 1) was launched in December 1966, providing an important communications link over the Pacific Ocean. It was designed originally for a three-year mission, but surpassed its design life by more than six times. The Hughes satellite carried several scientific instruments, including a spin-scan camera that provided the first wide-angle pictures of the Earth's full disc and helped meteorologists track storm fronts. ATS 1 also was used for communications during emergencies and for the day-to-day management of the U.S. Trust Territory of the Pacific Islands, a group of more than 2,000 islands more commonly known as Micronesia.

A cryogenic refrigerator designed to cool infrared sensors has passed a test equivalent to operating three years in space. The Vuilleumier cycle cooler, set in operation at twice its normal speed in order to simulate a design life of five years, has passed the year-and-a-half point of flawless operation. The device will be used with infrared sensors in space for applications such as defense and geological surveys. The sensors must be chilled to near absolute zero to maintain adequate sensitivity to low-temperature thermal radiation. The VM cooler, developed by Hughes, is believed to be the only one of its type to have performed this long at such low temperatures.

An experimental digital-to-analog converter chip is 10 times faster than the fastest conventional device. The chip, being developed at Hughes for advanced airborne radars, uses gallium arsenide as the substrate material. It has a settling time of 200 picoseconds, about an order of magnitude faster than a record-holding 6-bit Hughes silicon device. The new converter so far outdistances commercial devices that design engineers are developing special interfaces so that the device can be hooked up in data conversion systems for further testing and analysis.

Hughes Ground Systems Group is applying its airspace management experience to the exciting challenges of worldwide air traffic control. These systems will be designed to ensure service 24 hours a day, 7 days a week. They will support distribution of processing among multiple computers linked via local area networks. The many challenges include design and development of hardware and software to support advanced display and man-machine interface technology, and using satellite technologies for future ATC applications. To help design the next generation of air traffic control systems, send your resume to Hughes Ground Systems Group, Employment Dept. S2, P.O. Box 4275, Fullerton, CA 92634. Equal opportunity employer. U.S. citizenship required.

For more information write to: P.O. Box 45068, Los Angeles, CA 90045-0068

© 1986 Hughes Aircraft Company

HUGHES
AIRCRAFT COMPANY

Subsidiary of GM Hughes Electronics

PHONE FEATURES: THE NEXT WAVE

Services include automatic call-back, selective call forwarding, and call screening

by H. Paris Burstyn

Computerized call-routing switches have enabled phone companies to provide now-familiar "custom" services such as call waiting, call forwarding, three-way conferencing, and speed calling. But by the end of the decade, new switching software will expand these services considerably. By entering a two- or four-digit code, residential phone subscribers will be able to:

- automatically reconnect the last number that either called or was called;
- preselect up to 30 calling numbers to be forwarded to another location (selective call forwarding);
- be alerted by distinctive rings or call-waiting tones to incoming calls from preselected parties.
- trace calls in cooperation with local police; and
- block callers from designated numbers from ringing their phones.

These local-area signaling services (LASS) rely on four new software programs AT&T wrote for the switching computer that currently handles most phone calls, the 1A ESS. A version of LASS compatible with AT&T's most advanced switch—the digital 5ESS—is due for release in 1988. One program retrieves the directory number of the most recent incoming call. Another provides each subscriber line with a scratch-pad memory that continually updates the numbers of the last outgoing and incoming call. The third program automatically checks the status of the number being called (e.g., whether it is busy). Finally, a program maintains a memory file in which subscribers store selected numbers for special treatment, such as distinctive rings or nuisance-call rejection. As with existing custom services, subscribers will generally not need to buy or rent additional equipment, because the software resides in the phone company's switch.

What makes such software feasible is the recent trend toward "out-of-band signaling," whereby voice signals and the tones and pulses that represent phone numbers travel through two different circuits. Such independence, introduced by AT&T in 1976 for long-distance service and now available to local networks, means that the caller's phone number can be sent to the recipient without using up capacity on the voice channel. Out-of-band signaling also makes the phone system as a whole work more efficiently because calls placed to busy or nonworking numbers do not tie up the network. If a call can't be placed, the voice circuit is never set up, and a local intercept provides a busy signal or an invalid-number message. With in-band signaling, by contrast, a voice channel is opened up and reserved while the number is being routed and the status of the destination line is checked.

If served by LASS, someone who has just missed a call can automatically dial back the number by entering a code on either a tone or pulse phone. The central-office switch retrieves the number on the subscriber line's scratch-pad memory and checks that number's current status. If the call came in through the same central office, its status can be checked immediately. If it came via another office, then a message asking for the status is sent over the long-distance signaling network. Once the status information returns to the originating LASS switch, the call can be placed. All this signaling takes less than a second.

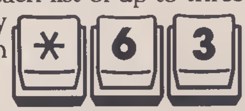
If the number is valid and the phone is on the hook, the call is set up as if it had been dialed normally. If the line is busy, LASS rechecks it every 40 seconds. At any time during the next half-hour when both the customer's number and the recalled number are idle, LASS gives the subscriber a special ring. If the phone is picked up, the call is placed; if not, LASS repeats the special ring every four minutes.

It's not necessary to wait

6. PREFERRED CALL FORWARDING℠

Select the calls you want forwarded.

In order to take advantage of PREFERRED CALL FORWARDING, you must have our Call Forwarding service. Then program your regular Call Forwarding, plus ✱63 (rotary and pulse dial[2] phones dial 1163) and up to three numbers of the calls you want forwarded. To deactivate, dial ✱83 (rotary and pulse dial phones dial 1183). After August 8, when you program PREFERRED CALL FORWARDING, the rate will be 25¢ for each list of up to three numbers, plus 5¢ per day to maintain the list in your phone line.



As emphasized in this promotion by Southern Bell, new phone features let users control who can reach them.

for reconnection before using the feature again. Once copied out of the scratch pad, the calling number is stored in a separate memory associated with automatic reconnect. The scratch pad can then be used to memorize the numbers of other incoming calls or to automatically redial outgoing calls.

One LASS service that aids in screening calls requires additional equipment. A device can be hooked up to the phone to display the number of an incoming call as the phone rings; it also stores the numbers of up to 30 calls that came in during the user's absence. Callers with unlisted numbers may activate a code that prevents their number from being displayed, but such a privacy code provides only limited anonymity. The LASS-controlled switch still records the number, so the subscriber can initiate a trace or request that future calls from the same number be blocked.

Aside from allowing new calling features, LASS will encourage systems that let customers enter data (such as credit card numbers) by tapping phone keys. Some banks and merchants already offer such services, but LASS's out-of-band signaling will make them much easier to set up. In addition, users will be able to talk over the phone while data are being transmitted to the same number.

From the phone companies' standpoint, LASS is an inexpensive way to make money. The new features add very little to the cost of the software needed to control the computerized switches; thus a low price can be charged with plenty of room for profit. In Bell of Pennsylvania's trial system, for example, the three most popular convenience features—automatic redial, automatic call return, and distinctive ring—are packaged together for \$3.75 per month. Alternatively, automatic redial and call return are priced at 15–20¢ per use. Selective call rejection is \$5 per month, and call tracing is \$3 per activation.

Besides Bell of Pennsylvania, LASS has been tried out by Pacific Bell and Southern Bell; these three companies were chosen before the Bell System breakup to test the services in different demographic areas. Bell of Pennsylvania finished its 9700-customer trial in Harrisburg at the end of 1985 but obtained an extension from state regulators. Within a year, the company says, it will file for a tariff granting permanent commercial service.

While the technology for LASS exists, widespread introduction of the services could be hampered by other factors. One uncertainty is the attitude of local public utility commissions. If they classify LASS as an "enhanced" communications service, the local telephone operating companies would be forbidden to offer it, under the rules of the Bell System divestiture. In that case, the regional Bell holding companies would have to establish separate subsidiaries to handle LASS.

Calls from selected numbers can be blocked, others identified by a distinctive ring; entering a short code lets you ring back the last caller.

Another obstacle is marketing. "Most people are not yet used to custom signaling services," says Gena Clifford, LASS product marketing manager for Bell of Pennsylvania. But she anticipates that the history of LASS will resemble that of automated teller machines, which were introduced in the late 1970s, took four or five years to catch on, and are now ubiquitous. Clifford's optimism is based on the customer reactions in her company's trials. "They don't need LASS to live," she says, "but once they get used to it, they can't live without it." □

H. Paris Burstyn is an analyst with the World Telecommunications Information Program at Arthur D. Little (Cambridge, Mass.).

YOUR SHARE OF HIGH TECH SUCCESS

awaits in High Technology's Classified Section. Here you'll reach both technical and management types whose innovation and action put them at the top of today's hottest industry. And whose budgets and buying patterns can put them at the top of your sales list.

High Technology's Classifieds offer a variety of categories to effectively position your ad. At cost efficient rates that prompt frequent insertion.

If you're ready to claim your share of the high technology bonanza, claim a spot in the High Technology Classified Section. For further information, contact Linda Conti, High Technology, 38 Commercial Wharf, Boston, MA 02110-3883 (617) 227-4700.

highTechnology

And then there were none.

The list of already extinct animals grows . . . the great auk, the Texas gray wolf, the Badlands bighorn, the sea mink, the passenger pigeon . . .

What happens if civilization continues to slowly choke out wildlife species by species?

Man cannot live on a planet unfit for animals.

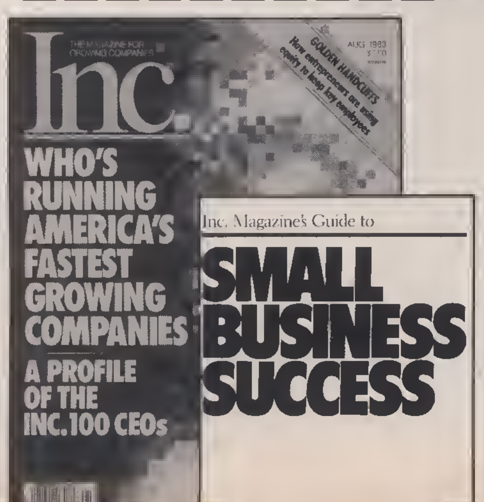
Join an organization that's **doing** something about preserving our endangered species. Get involved. Write the National Wildlife Federation, Department 105, 1412 16th Street, NW. Washington, DC 20036.

It's not too late.

If you're running a growing business you may find you're playing doctor more than you'd like. Everyday problems arise that can slow down the growth of your company. And whether it's too much paperwork or too little capital you're the one that's got to take time to get things back on track.

At Inc. we make it our business to deliver solutions to your company's problems. We give you access to the methods and ideas that the country's most successful growing companies have used to solve difficulties like yours. And better yet, we'll show you how to put those solutions to work in your own business. And that's the kind of medicine that can help you spend a lot less time playing doctor and a lot more time playing leader.

Use the accompanying card to subscribe to Inc. Do it today and we'll send you absolutely free a copy of *Small Business Success;* a collection of 100 proven techniques to help your business grow.



Order Inc. at 50% off and Receive a Free Copy of *Small Business Success*.

☐ **Rush me a year (12 issues) of Inc. for $18.** I'll save 50% ($36) off the cover price. Also I'll receive a free copy of *Small Business Success*.

☐ **I prefer 3 years (36 issues) for $36.** I'll save 66% ($72) off the cover price. And I'll still get a free copy of *Small Business Success*.

☐ Payment enclosed ☐ Bill me later

NAME ____________ TITLE ____________

COMPANY ____________

ADDRESS ____________

CITY ____________ STATE ______ ZIP ______

Offer good in U.S. only. Please allow 4-6 weeks for delivery.

Mail coupon to: Inc., P.O. Box 2539, Boulder, CO 80321 5AKP6

LIFE IN THE FAST LANE

Accessories like disk caches and coprocessors can give your micro a speed boost

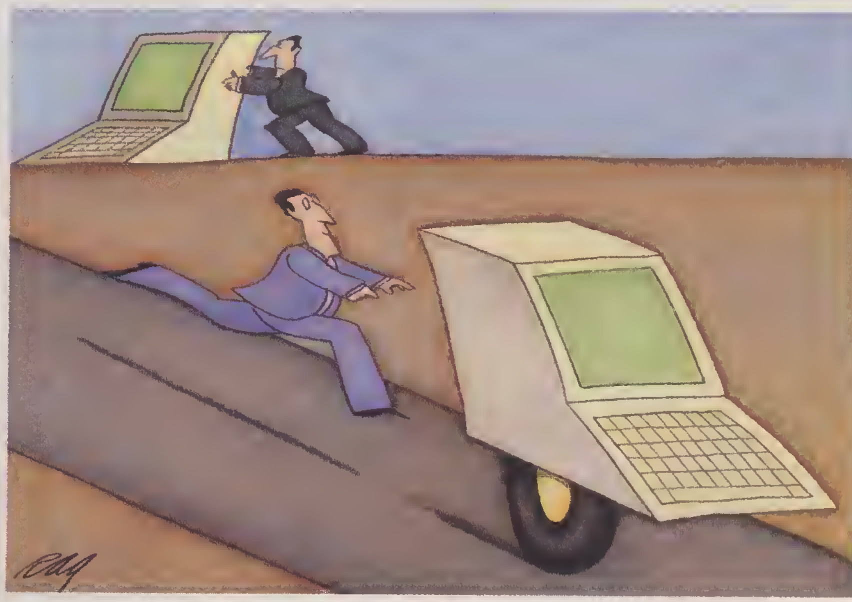
Speed is the essence of computing. Despite advertising claims, computers don't necessarily help us work better or smarter; but they almost always help us work faster.

Just what improvements a faster computer can offer vary greatly with specific situations. For routine work with traditional, text-based word processors, greater speed may make little difference except in search-and-replace functions; spreadsheet users may see only modest differences with small spreadsheets. The new graphics-based programs are computationally intensive, however, and require the latest and fastest computer designs for adequate operation. One warning: if you try a faster machine, you will be spoiled and all slower machines will seem faded and old-fashioned.

You can get more speed either by changing to a fundamentally faster computer or by adding accessories. For older models, the aftermarket manufacturers have developed many add-on devices to speed operation. The numerous options have become especially confusing because advertising usually concentrates on a single parameter, whereas overall computing speed depends on many factors. The most common speed benchmarks calculate prime numbers, a task few people ever do, and in any event only measure raw processor speed, not overall throughput. In fact, such benchmarks aren't always a good measure of processor speed; unless comparing similar processors, they mostly test the efficiency of a computer language interpreter or compiler.

Assuming that the software remains the same, overall performance can be improved by hardware changes in processor speed, bus bandwidth, and disk drive speed. IBM, in designing the PC/AT, made improvements in all these areas over its earlier PC and PC/XT. The aftermarket developers concentrating on the 8088-based PC and PC/XT usually address only one or two factors. Other speed improvements can be gained by adding random-access memory (RAM), numeric coprocessors, printer and disk buffers, and some forms of operating environment software.

by Cary Lu



RICHARD A. GOLDBERG

If you want fast operation within the IBM world, get a PC/AT or a good clone. If you buy a clone, make sure it will accept a full-height $5^1/_4$-inch hard disk drive; high-capacity, high-performance drives come only in the full-height size (HIGH TECHNOLOGY, May 1986, p. 60). Look for a fast, voice-coil hard disk with an access time of under 28 milliseconds. Avoid the widely advertised "bargains" that use drives with longer access times (often 95 milliseconds) or clones with a chassis that accepts only half-height hard disks. If you have an AT with its original hard disk drive (about 38 milliseconds access time) consider upgrading, not only for speed, but in many cases for reliability.

To improve disk performance further, you can use RAM as a simulated disk drive or a disk cache. RAM disks have been popular, since they are easy to understand and use, but have one critical limitation—they are volatile and disappear when the power goes off. On a PC/AT, you can create a RAM disk with up to 15 megabytes (MB) of storage, using memory at addresses above 1 MB. Memory at these addresses does not take away from your main 640-kilobyte (kB) working memory, an important consideration since some programs need as much as 512 kB or more. (RAM disks and disk caches on older PCs generally must occupy part of the main 640-kB memory space and so are severely restricted in size.) If 15 MB seems a little excessive, at least put in 2 or 3 MB, which is enough for many applications. When in doubt, add more memory; you can never have enough.

A disk cache acts as a large buffer between the central processor and the disk drive. The buffer holds the most recently used information read from and written to the disk. Whenever the computer needs information, it looks in the cache first; if the information is already there, it can be retrieved immediately without waiting for the physical disk drive. Because the cache contents are written to the disk automatically, power failures constitute a

less serious problem.

Disk caches are usually better than RAM disks for complex jobs employing many programs and files, since you don't have to install specific files in a RAM disk. RAM disks are better for simpler, clearly defined applications with a limited number of files that you use over and over. The BUFFERS command in MS-DOS is a simple disk cache, but it uses up main memory, it works only on a hard disk, and its file-search scheme can slow down operations when the cache is large. Other cache programs work more efficiently and will cache the floppy disks as well.

The Flash disk-cache program combines the best of both worlds, providing not only caching but also the advantages of a RAM disk; you can set files to stay resident in the buffer regardless of other activity. With a big enough cache—say 3 MB—this is the most effective way to use RAM to speed up computing.

Additional memory can also save time by serving as a printer buffer, letting you continue working at the keyboard while the printer chugs away. Many companies sell external printer buffers—little boxes with a power supply and memory that connect a computer and printer. In most single-user situations, however, these external buffers are expensive and offer little advantage over a buffer in the computer's RAM, unless you have a PC and cannot give up part of the 640-kB memory space to a buffer.

Instead of installing the additional RAM at above-1-MB addresses on an AT, you could go with the Lotus/Intel/Microsoft Enhanced Memory Specification (EMS) or AST's variation. EMS is a crude but modestly functional stopgap measure to sneak around the DOS 640-kB limit, if your software can take advantage of it (most can't). If you get an EMS board for the PC/AT, make sure that the memory is switchable to above-1-MB addressing as well. The EMS memory does give owners of older PCs a way to create larger RAM disks without cutting into their 640-kB main memory if you are convinced the $400–$2000 price is acceptable.

(Ultimately, the over-1-MB memory on the PC/AT will be available for running application programs, when PC-DOS/MS-DOS gets past the 640-kB limit; the Unix/Xenix operating system can already use the memory for applications.)

The most publicized speedup for the earlier PC/ATs swaps the standard 6-megahertz (MHz) clock crystal to increase the speed to 8 MHz or more. IBM has discouraged this practice by producing new ATs with a speed check during start-up that shuts down the computer if the crystal speed has been changed. IBM's speed check is easily circumvented, however, by a clock circuit that runs at 6 MHz during the check and then changes to a higher speed afterwards. BGI and Megahertz synthesize the clock signal instead of switching mechanically between crystals. The mechanical switches do work, but can occasionally produce a glitch if you switch during operation.

If your AT does not perform the speed check, a simple crystal change will do; prices are under $15. In some cases you may need to restore normal speed temporarily for a few copy-protection schemes and the occasional programs that will run only at 6 MHz because of poor design.

How fast will a particular PC/AT run? Most run reliably at 8 MHz, although a few early units need to change the 80286 central processing unit (CPU) chip. To go faster than 8 MHz raises some problems, according to Bernie Roemel of BGI. Faster operation increases heat generation, and even though many standard PC/ATs can run at 9 MHz or even a little faster, the heat may eventually cause the CPU to fail. At 10 MHz, you will usually need to change to a 10-MHz 80286 and 120-nanosecond (ns) memory chips instead of the common 150-ns variety. Going past 11 MHz usually requires a 12-MHz 80286 and 100-ns memory. Suitably equipped, most PC/ATs can run at 11.5 MHz, provided that memory cards and other accessories can take the speed. At higher speeds, a keyboard checking circuit may inhibit operation. The Hercules board and all IBM video boards except the Professional Graphics Adapter will run at 12.5 MHz, but many other boards, particularly the low-cost clone boards, will not work above 10 MHz. Many memory boards will not run faster than 8 MHz; look for designs such as those by Cheetah International and BGI that have been tested at higher speeds.

Numeric coprocessors, such as the Intel 80287 for the PC/AT and the 8087 for the PC, speed up computing by taking on numerical calculation tasks and freeing the main CPU for other work. These coprocessors work only if the software has been modified to use them. Few application programs require a coprocessor, but the devices can significantly boost the speed of CAD programs, spreadsheets, and other computationally intensive applications. Programs that deal mainly with text, such as word processors and databases, generally show little improvement and have not been adapted to use coprocessors. Users installing 80287s in PC/ATs have sometimes been disappointed because the relative speed improvement is less than for the 8087 on a PC. The reason lies in the speed of the 80287, which normally runs at two-thirds of the 80286 CPU's speed, or 4 MHz on a stock PC/AT. The 80287 can operate independently of the system clock, however; Hauppauge, MicroWay, and others sell small circuit boards that boost 80287 speeds to 8 MHz. These boards include an 8-MHz 80287; Intel has samples running at 10 MHz and says 12 MHz is possible.

Companies

BGI Computer Division, 118 N. Main St., Trumbauersville, PA 18970, (215) 538–3900
Cheetah International, 107 Community Blvd., Suite 5, Longview, TX 75602, (800) 243–3824
Dynamical Systems (Mondrian), 2511 Fulton St., Berkeley, CA 94704, (415) 530–9151
General Computer, 215 First St., Cambridge, MA 02142, (617) 492–5500
Hauppauge, 358 Veterans Memorial Hwy., Commack, NY 11725, (512) 360–3827
Levco, 6160 Lusk Blvd., Suite C203, San Diego, CA 92121, (619) 457–2011
Megacalc, 3750 Peacock Ct., Bldg. 1, Santa Clara, CA 95051, (408) 296–1234
Megahertz Corp., 50 S. Main St., Suite 600, Salt Lake City, UT 84144, (801) 355–8857
MicroWay, PO Box 79, Kingston, MA 02364, (617) 746–7341
SoftLogic Solutions (DoubleDOS), 530 Chestnut St., Manchester, NH 03101, (603) 627–9900
Software Masters (Flash), 6223 Carrollton Ave., Indianapolis, IN 46220, (317) 253–8088

For even faster numeric coprocessing, Megacalc's Cruncher board takes common 80287 and 8087 instructions and runs them through a pipelined processor. The speed improvement from this expensive ($1400–$1600) and specialized board will depend on how your software works.

If you have an 8088-based PC, you should certainly fill out its memory to 640 kB and perhaps add a hard disk. Most other speed enhancements are not cost-effective. Many companies offer speed enhancement boards that replace the 8088 CPU, but the cost is high, generally over $500, and often much more, particularly with a full complement of memory. Assuming that you start out with an IBM PC, the upgrades effectively leave you with a clone. Cost comparisons almost always show that trading up to a PC/AT or the equivalent is a better choice, particularly since the PC/AT's design addresses many speed issues, not just the CPU speed.

Software can effectively speed up operation in several ways. Operating environment software can let you load several programs into memory. Although the programs will not execute any faster—sometimes they will run slower—you will be able to switch programs quickly without having to unload and load, and find your place again. Microsoft Windows is the most advanced of these products, although few existing application programs take full advantage of its features. IBM's TopView is bettered by Mondrian, a faster, more compact program with the same functions. DesqView performs similar functions. The straightforward DoubleDOS and similar products don't do any fancy windowing; they simply let you switch instantly between two tasks.

Unfortunately, all these operating environments—as well as Digital Research's Concurrent DOS, which multitasks by replacing MS-DOS altogether—suffer from assorted compatibility problems. Many application programs weren't designed to share memory with another program; some slow down, some ignore keystrokes, and others just won't work. You may spend more time getting everything to work than you can save later. Eventually, products designed for true multitasking will fix these problems.

The Apple Macintosh uses an 8-MHz 68000 CPU, a respectable performer. Its worst speed bottleneck comes from slow access to disk drives (even on the new SCSI hard disk interface, which does not run at full speed on the Macintosh Plus)—a problem compounded by sophisticated software that performs many more functions than the IBM PC equivalent. Two companies have developed hardware speed improvements. General Computer's $3500 HyperDrive 2000 installs a 12-MHz 68000, improves the memory access, and adds a 68881 numeric coprocessor. Levco goes farther at a higher cost (estimated at $7000–$9000): a 16-MHz 68020 processor with true 32-bit operation, a 68881, 4-MB memory, and a fast hard disk port. The 68020 will run all programs written for the 68000 much faster—although, again, only modified software can take full advantage of the hardware.

For best performance on the Macintosh, you will need a fast external hard disk; the smaller hard drives that can be installed inside the Mac are all low-performance designs.

On the software side, Apple's Switcher program lets you load multiple programs into memory, switch among them instantly, and pass information back and forth. Although there are some minor compatibility problems, Switcher works much more smoothly than any corresponding IBM PC product.

The future will bring greatly increased speeds to our desktops. Today's micros run at about 0.5 to 0.8 MIPS (million instructions per second, a common but limited figure of merit). The next generation should get to 1.5–3 MIPS (Levco's modified Macintosh is already over 2 MIPS), and the generation after that, 5–10 MIPS. The only certainty is that, despite their speed, these forthcoming models still won't be fast enough. □

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

What is a Best Western?

The right place at the right price.

Make reservations at any Best Western, see your travel agent, or call toll-free
1-800-528-1234

"World's largest chain of ***independently owned and operated*** *hotels, motor inns and resorts"*

The Answer is:

No one.

See reverse side for

The Question

DINERS CLUB PREFERRED STATUS MEMBERSHIP FORM

Please print your full name as you wish it to appear on the Card.

Please print your business title or company name as you wish it to appear on the Card.

ADDITIONAL CARD: Please issue an additional Diners Club Card, $25 each annually, with separate monthly itemized listing for the above family or household member. **Married Applicants may each apply for separate accounts.**

– – / / Number of dependents (include yourself) ______

Social Security Number Birth Date

Highest Level of Education Completed:
☐ High School ☐ College ☐ Graduate School

Home Address Street

City State Zip

( ) Years at current address: ______ own ☐ rent ☐ ______ other ☐

Home Telephone (include area code)

Previous Home Address (if less than 1 year at present address)

City State Zip

Indicate your banking relationships:

Bank Name ☐ Checking ☐ Savings ☐ Money Market ☐ NOW ☐ Other ______

Bank Name ☐ Checking ☐ Savings ☐ Money Market ☐ NOW ☐ Other ______

Check which charge cards you have:
American Express ☐ Visa ☐ MasterCard ☐ Oil Company Cards ☐
Sears ☐ Wards ☐ J. C. Penney ☐ Other Store Cards ☐

Employer Name Your Position

Employer Address Street

City State Zip

( ) Self-employed: Yes ☐ No ☐

Business Telephone (include area code)

Annual Wages or Salary (must be provided): ______

If your annual salary is less than $25,000—indicate source and amount of other income, and individual (Banker, Broker, Employer, etc.) we may contact for confirmation. Please understand that your total annual income from all sources **must** be at least $25,000 to be considered for Cardmembership.

Disclosure of income from alimony, child support or separate maintenance required only if you wish it to be considered for purposes of this application.

Other income $ ______ Source ______

Name of individual for additional income verification. Phone

Address City State Zip

Please provide all requested information so your Membership Form may be promptly processed. If Citicorp Diners Club is unable to approve it, you agree that we may forward this Membership Form to another issuer of the Diners Club Card who may also investigate your credit history. (Insurance, rewards benefits and other terms and conditions vary with issuer.) Send no money now. Upon our approval, we will bill you for the non-refundable $55 annual MEMBERSHIP FEE (subject to change).

I have read both sides of this application and agree to its terms.

X

Signature of Primary Applicant Date

X

Signature of Additional Applicant, if any (Additional Applicant agrees to be equally responsible for all charges made with the Card.) Date

Special Offer:
You will receive a total of 12 issues of Signature, the Citicorp Diners Club magazine, for $12.95 ($5.00 off the Diners Club Cardmember rate). Or you may choose to write "cancel Signature" across the payment stub of the statement on which you are billed for the remaining issues. Keep the first 3 issues with no further obligation. Do not enclose check—we will bill you later.

SEE REVERSE SIDE FOR IMPORTANT INFORMATION FHD2C2

Apply Today for The Card That Takes Care of You While You Take Care of Business.

The Question: Who besides Diners Club gives you all these?

1. FREE Travel and Gifts for Your Spending?
It's all part of **Club Rewards℠** and it works just like an airline frequent flyer program. Every time you charge on the Diners Club Card, you automatically earn points toward FREE trips on United Airlines and FREE gifts* — from a night on the town to a personal computer. And the more you use Diners Club, the more you're rewarded.

2. $650,000 Automatic Air Travel Accident Insurance at no extra cost?
Simply charge your airfare to the Diners Club Card. You're covered automatically.†

3. A Luxurious 2-Room Hotel Suite for the Standard Price of a Single Room?
Enjoy **Club Suites℠** in selected premium hotels in key U.S. cities.**

4. A Ride in a Chauffeur Driven Sedan for Only a Few Dollars More than the Price of a Taxi?
Take advantage of **Club Chauffeur℠** between major airports and downtown business centers in selected U.S. cities.**

5. Your Own Personal Gift Consultant?
Club Gifts℠ offers you a time-saving personalized service to call when you want to give a gift that's truly special — even unique and unexpected — to the important people in your personal and business life.***

In addition to these special benefits, you enjoy the basic privileges you expect from a prestigious travel and entertainment charge card. Like **Virtually Unlimited Spending Privileges** — there's no arbitrary limit on your spending — you set your own limit through your spending and payment patterns. And **Worldwide Acceptance** means you'll be welcomed at over 800,000 establishments in 150 countries.

For Answer See Reverse Side

*Club Rewards is a service available only to Personal and Company accounts located within the 50 United States. Enrollment required. Certain terms and conditions apply.

†This policy is underwritten by Commercial Insurance Company of Newark, N.J. The cost of the travel accident insurance is $.51 per trip. Costs are included as part of the annual membership fee. The coverage is not available to Corporate Cardmembers.

**Certain restrictions, reservation and cancellation policies apply for Club Chauffeur and Club Suites. To avoid possible charges call your Club Representative at 1-800-CLUB-INFO (1-800-258-2463) for more information.

***Some fees apply.
Specific benefits and rewards subject to availability and may be changed without notice.

Apply for the Diners Club Card Today!
Application on Reverse Side

NO POSTAGE NECESSARY IF MAILED IN THE U.S.

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 3930 DENVER, CO

POSTAGE WILL BE PAID BY ADDRESSEE

CITICORP DINERS CLUB
P.O. Box 17589
Denver, CO 80217-9908

CITICORP DINERS CLUB

Applicants please note: By signing this Application Applicants authorize Citicorp Diners Club to investigate their credit worthiness. Consumer reports may be requested in connection with the processing of this Application and subsequently in connection with any renewal, or extension of credit. Upon request, Citicorp Diners Club will inform each Applicant of the names and addresses of any consumer reporting agencies which have provided us with such reports.

Applicant(s) agrees that use of any Card(s) issued as a result of this Application will be governed by the Agreement provided at the time the Card(s) is issued. All Applicants agree to be jointly and severally liable for all charges made on the Account and on any additional Cards issued pursuant to the Account.

© 1986 Citicorp Diners Club Inc.

MACHINE TRANSLATION POISED FOR GROWTH

Software for translating natural language gets practical

Automatic translation of natural language has been a dream of programmers and computer users ever since the computer was invented. But the first attempts at applying machines to translate, say, from Russian to English, were abject failures. The early researchers—working in the then-embryonic field of artificial intelligence—didn't take into account the complexities of language, with multiple potential meanings for each word based on context. More often than not, the resulting word-for-word translations contained incorrect and nonsensical sentences.

Even today, with bright prospects in AI applications such as expert systems, the barriers to fully automatic translation remain great. It may be some time before you can take a French-language report, feed it into the optical character reader on your office's translation machine, punch "Input–French" and "Output–English" buttons, and receive a perfectly translated copy a few moments later.

Still, machine translation is beginning to establish itself as a useful tool, largely because its developers have positioned it as an aid to human translators, not as a fully automated process. The products of three companies—Automated Language Processing Systems (ALPS–Provo, Ut.), Weidner Communications (Northbrook, Ill.) and Logos Computer Systems (Wellesley, Mass.)—represent the state of the art in commercial translation software. Each company approaches the translation task in a different way, but they are similar in that they make no claims of performing totally automatic translation.

Because current software can neither use information contained in surrounding sentences nor apply world knowledge to the translation task (see sidebar), all of the available machines translate by reading each sentence in isolation. The software packages are also similar in that each takes the user through a dictionary-building phase. When presented with a new document to translate, the machines scan it and produce a list of words they don't recognize. The user can then enter a definition along with other information about each word for the machine's future reference.

by Charles Connell

Beyond these product similarities, some differences emerge. ALPS' product, for example, is designed to work in an interactive manner, with the translator guiding the software through the text, one sentence at a time. The products from Weidner and Logos operate in batch, with the software making a first pass at the translation and a human translator editing the output.

In the belief that people are an essential part of the translation process and that the proper role of a machine is to allow human translators to work more quickly, ALPS bills its products as "tools to aid translators." A central feature of the ALPS Transactive software is the tools provided for this person/machine exchange: a multilingual word processor and access to on-line dictionaries in both languages.

Machine translation is being positioned as an aid to human translation, not as a fully automated process.

The ALPS software runs on the IBM PC/AT under the Xenix operating system, on Data General MV series minicomputers running the AOS/VS operating system, and on IBM 4300 series computers running the VM/CMS operating system. It supports translation from English into French, German, Italian, and Spanish, and from French into English. Each one-way language pair costs $13,000 per workstation running the software; for example, the price of one pair running on a multiuser computer with three terminals would be $39,000.

Weidner Communications agrees that "the human will never be replaced," but follows a different strategy: It lets the machine get first crack at a full document translation. Using Weidner's products, a customer submits the entire text to the translation software (after the dictionary-building phase) and receives a rough output, which may then be polished by a human translator.

Weidner's MacroCAT software runs on Digital Equipment's VAX/VMS computers; a scaled-down version, MicroCAT, runs on the IBM PC/XT. The available translation pairs are English to French, Spanish, German, Italian, and Portugese; French to English; and Spanish to English. German to English and Japanese to English are available for the MacroCAT version only. Weidner also supplies a text editor that allows split-screen viewing of the source and target texts at the same time. Pricing of the software depends upon the number of language pairs. The cost of two directions of translation (for example, English to French and French to English) would be approximately $50,000; for four directions, about $85,000.

Logos Computer Systems makes a product that is similar to Weidner's. Texts are translated in batch, with a human translator performing editing and verification. Logos says that its product is good enough to be treated as a "junior translator reporting to a human senior translator." The company has developed a universal intermediate language, the Semantic Abstraction Language (SAL), which serves as an intermediate code for all its translations. The source language is scanned once (after dictionary building) and changed to SAL. The SAL for the text can then be read any number of times and, in theory, changed to several languages without further reference to the source. In practice, Logos hasn't yet attained its goal of universal trans-

lation from the SAL code, since, like its competitors, it sells its software in specific language pairs. The Logos software runs on Wang VS and IBM VM/CMS systems and is available in English to German, English to French, and German to English pairs. Logos licenses, rather than sells, its software. The company declined to release pricing information.

Roger Jeanty, a participant in the evaluation of several translation machines, cautions that while machine translation systems can be valuable tools, their limitations must be recognized. In fact, says Jeanty, who is executive vice-president of the International Software Centre (Natick, Mass.), which translates software documentation and user interfaces, these systems can make the job more difficult for human translators if not used properly. For example, "there is a vogue in U.S. computer documentation to take the user-friendly approach, with frequent use of 'you' when addressing the reader," he notes. "If you translate this literally to French or German, however, the readers in those countries will find this style odd, if not derogatory. A machine will not understand this cultural difference, and it can take a long time to manually clean up a translation that has the wrong tone."

Because subtleties such as tone and innuendo can easily be missed by machine translators, says Jeanty, the products can be virtually useless for translating material such as advertising, which is rich with underlying meaning. A suggestion of intimacy and romance, for example, might be turned by a translation machine into blatant and outrageous suggestions. On the other hand, he says, translating straightforward material such as weather forecasts can often be performed almost totally automatically by machine.

Regarding the two main translation approaches—batch and interactive—Jeanty says that, "in theory, a batch approach is better. You just turn the machine on, go home, and pick up the translation the next morning. Given the current state of the art, however, I favor interactive machines. They allow a human translator to immediately correct errors that the computer is certain to make."

Machine translation is currently about a $10 million annual business in the U.S., and growing at about 30% per

Why machines have trouble with linguistics

Translating from one language to another involves problems at three linguistic levels. The first involves understanding the syntactic structure of sentences in the source language so that they can be translated to equivalent sentences in the target language. This is not always so simple, as the following two sentences illustrate:

"IBM's Model 360, which had a strong impact on the data processing world for many years, has lost ground to the minicomputer revolution."

"Don't turn off your personal computer before waiting for the red light on the hard disk drive to go off."

The first sentence is a statement with "Model 360" as the subject, "IBM" as a possessive adjective modifying the subject, and "which had . . . for many years" as a relative clause. The second sentence is a command. The subject, "you," is implied, and the sentence contains a compound noun phrase, "hard disk drive." Someone who knows English understands these grammatical facts, although this knowledge may not be conscious.

Translation software faces the problem of performing this kind of analysis on every sentence it processes. Such software relies on parsers, which identify the parts of speech in a sentence by diagramming "parse trees" that show the relationships between words and the phrases they form to create full sentences. The examples given are quite simple, but more complex sentences can have many layers of syntactic structure. Adding to this difficulty is the fact that linguists have not produced a full grammatical description of English or any other language. A great deal of what we know about grammar is not accessible to us—we can use it properly, but we cannot write down its rules. Translation machines are thus constrained by the state of the art in linguistics.

After understanding the syntactic structure of a sentence, the next problem involves making use of information across sentence boundaries. The core of the problem is easy to state: A sentence does not fully determine the meaning of its words. We decide on word meaning through context, as illustrated by the next examples:

"The jewel thief had spent many enjoyable hours playing by the river as a small child. Now that he had to find a place to stash the diamonds, he hid them in the bank."

"The jewel thief had been a trusted employee of First Savings and Loan for many years and knew that no one there would suspect him. Now that he had to find a place to stash the diamonds, he hid them in the bank."

The second sentence in each example is identical, but we associate different meanings with the word "bank" in each case because of the information in the preceding sentences. As a result, there is no way to confidently understand or translate these examples by reading each sentence in isolation. A translator (human or machine) must build up a scene or "context" while reading. The translator then uses the context to choose a correct translation for each word. Building a description of a context, however, is one of the classic problems in the philosophy of language, and little progress has been made at achieving such a description.

These two factors, sentence structure and context, pose a serious challenge for translation by machine. But there is an even harder problem. Human translators are able to consider factors external to the document they are reading. By knowing the purpose of a piece of writing or its context in the world, they can often understand what a writer intended to say, even when it is not directly stated. The following examples illustrate this point:

"When moving the Cray 1 supercomputer, pay careful attention to safety precautions since it weighs 3 pounds."

"This software has the nice feature of tying together several related functions. And the ability to print four-color reports every month."

The first example is gramatically correct and very clear. A human translator, however, would recognize that it doesn't make sense, knowing that a

supercomputer cannot weigh 3 pounds (and that if it did, safety precautions would not be necessary). The translator would conclude that some zeros were lost from the number specifying the weight, and would check the facts. The second example contains a sentence that, strictly speaking, is ungrammatical and unintelligible. A translator can assume that it is an editing error, though, and can combine the two sentences into one. Unfortunately, representing such general knowledge in a translation program is an unsolved problem.

Of the three linguistic levels required for accurate translation—syntactic analysis, information sharing between sentences, and general world knowledge—only the first is fairly well understood and present in current translation products. Determining a sentence's meaning based on its relationship with other sentences is not so advanced, although it represents a hot area of AI research and progress can be expected in this field.

Creating a computer with a broad base of world knowledge, however, is a problem of profound difficulty. The scope of an average person's knowledge far exceeds that which can feasibly be programmed into any computer. Also, to fully understand tone and innuendo, a computer would need a sense of culture and would have to understand, if not actually feel, emotions. Giving a machine such ability is far beyond the current state of the art in computer science and will not occur in the foreseeable future.

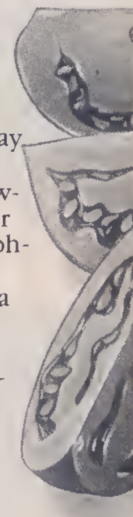
Roger Jeanty, executive VP of a translation firm, says machines can easily translate simple copy such as weather forecasts, but can miss subtleties in complex material.

year, according to Harvey P. Newquist III, editor of the *AI Trends Newsletter* (Scottsdale, Ariz.). He believes the growth could be greater if the technology were better understood by U.S. companies. "Corporate America is just coming out of the toddler stages in computing," he says. "Machine translation is exciting, but exotic, and it therefore often scares them."

So far, Newquist notes, machine translation remains a relatively minor field of artificial intelligence, with just three companies selling translation software compared with about 80 companies producing expert systems products. "But just as with expert systems," he says, "a few commercial success stories will bring many others into the field." □

Charles Connell is a consultant in Newton, Mass., specializing in system programming and translation.

A defense against cancer can be cooked up in your kitchen.



There is evidence that diet and cancer are related. Some foods may promote cancer, while others may protect you from it.

Foods related to lowering the risk of cancer of the larynx and esophagus all have high amounts of carotene, a form of Vitamin A which is in cantaloupes, peaches, broccoli, spinach, all dark green leafy vegetables, sweet potatoes, carrots, pumpkin, winter squash, and tomatoes, citrus fruits and brussels sprouts.

Foods that may help reduce the risk of gastrointestinal and respiratory tract cancer are cabbage, broccoli, brussels sprouts, kohlrabi, cauliflower.

Fruits, vegetables and whole-grain cereals such as oatmeal, bran and wheat may help lower the risk of colorectal cancer.

Foods high in fats, salt- or nitrite-cured foods such as ham, and fish and types of sausages smoked by traditional methods should be eaten in moderation.

Be moderate in consumption of alcohol also.

A good rule of thumb is cut down on fat and don't be fat. Weight reduction may lower cancer risk. Our 12-year study of nearly a million Americans uncovered high cancer risks particularly among people 40% or more overweight.

Now, more than ever, we know you can cook up your own defense against cancer. So eat healthy and be healthy.

No one faces cancer alone.

AMERICAN CANCER SOCIETY®

The future isn't tomorrow.

It's today.

Run faster.

Because now—as never before—you need to hurry up to keep up.

Change—dazzling, dizzying, dumbfounding change—is sweeping you into a world different than any in history.

And that's why one magazine is prerequisite reading to the managerial elite.

A magazine that brings the business of technological change down to the matter of business applications—and the business of technology down to the bottom line.

A magazine that helps you catch up—and move ahead—at a time when technology is changing the way your world turns.

A magazine called *High Technology.*

It's published by the same people who brought you Inc. With the same care, the same concern, the same understanding of your needs.

Some call it High Technology, others call it High Tech.

But call us. And you'll learn we ought to be on your next media schedule for reasons no other publication can offer.

For starters, the audience.

You won't reach High Tech's fast track readers with other publications.

Since fewer than 31% of our subscribers are regular readers of 17 major business and technical publications. (And that list includes the leading daily, the leading newsweekly, the leading business magazine, the leading computer publication.)

Average household income? *$86,800* —and moving up fast.

Average individual employment income? *$73,200*—which puts them ahead of the pack.

Average net worth? *$693,200*—proof they've outrun all the rest—and for years.

They work in companies that have, on average, more than 24,000 employees.

And more than one in four hold *top management* positions. Which is where the fast track leads, of course.

But beyond stark demographics, what distinguishes High Tech readers is the same thing that differentiates high tech from low tech.

High tech is *today*—and the future. Low tech is *yesterday*—and the past.

And that brings you to this critical decision.

Do you intend to live in the past? Or in the future?

The future isn't 2001, or 1990 or next year. Or even tomorrow. It's now.

That's why you belong in High Technology. As a reader. And as an advertiser.

So you'll run, not in panic, but with purpose.

HIGH TECHNOLOGY

The magazine that's a must in your fast-moving world.

Learn more about High Technology. Just call your High Tech representative and he'll dash right over.
In NEW YORK, Mark Anderson, Desmond Abicair, Art Santucci, or Joe Griggs at (212) 687-6715;
in BOSTON, Bob Boris at (617) 749-2196; in CHICAGO, Tom Fitzpatrick or Nancy Brown at (312) 653-1611;
in DALLAS, Marcus Loy or Jeanne Ingersoll at (214) 680-0684; in DETROIT, Don Rowe at (313) 373-3950;
in JACKSONVILLE, Jim Cerbone at (904) 427-0356; in LOS ANGELES, Carroll Walters at (213) 474-3332;
in SAN FRANCISCO, Walter Forsiak at (415) 461-8366.

SDI SPINOFFS: UP IN THE AIR

Will the civilian sector benefit from Star Wars technology?

If present research on the Strategic Defense Initiative finds the concept to be technically and economically practical, the U.S. government could spend hundreds of billions of dollars in the 1990s and beyond to develop and deploy the system. The Reagan administration already plans to spend more than $30 billion by 1990. This would of course provide an enormous amount of business for defense contractors and other high technology industries. But how soon, if ever, will SDI produce commercial spinoffs? The answer depends on who you talk to. Many managers and supporters of SDI foresee significant commercial benefits in the near future. Critics, meanwhile, maintain that most of the program's technology will be either wrapped up in red tape for years to come or inherently unsuited to civilian applications.

SDI officials are quick to assert that the value of the program does not depend on its civilian spinoffs. But they are also eager to use the lure of these benefits to win support for the ambitious undertaking. Thus the SDI Organization's director, Lieutenant General James Abrahamson, created an Office of Educational and Civil Applications last fall to promote commercial and other uses of SDI research.

An SDI missile defense system will require major advances in many different areas of military technology—sensors, high-speed missiles, lasers, particle beam accelerators, control devices, power sources, materials, and computer hardware and software. Converting research in such areas into salable products won't be easy. Companies will have to run a gauntlet of classification procedures, export controls, and slow development cycles before they can hope to cash in.

by Kevin Finneran

Defense Department insiders are generally optimistic, however. SDI chief scientist Gerold Yonas points to space surveillance research, which accounts for 35–40% of SDI spending, as an area in which "spinoffs are expected into every part of the economy." Brigadier General Robert Rankine, Air Force special assistant for SDI, believes that tracking and pointing technology developed for surveillance "may prove valuable in commercial aircraft guidance and in ground traffic monitoring." He also sees potential applications for very precise sensing and measurement technology in automated process control.

SDI program managers expect numerous commercial spinoffs from laser weapons as well. Rankine envisions SDI research contributing to the use of monochromatic radiation in CT scanners, which would reduce the dosage of radiation necessary for diagnosis while providing higher resolution that "would allow discrimination between molecular species, not just between density variations." He also sees a potential for laser etching of microelectronic components. Other likely spinoffs suggested by SDI staff, researchers in the national laboratories, and defense contractors would benefit such areas as energy generation and storage in space, supercomputer hardware, software for artificial intelligence systems, and hybrid optical-electronic computers.

At the same time, SDI officials warn against expecting too many specific products to emerge from the research. "People miss the point when they emphasize widgets," says chief scientist Yonas. "The real commodity is the knowledge base, whose benefits are indirect but still real." Colonel Joseph Rougeau, director of SDI's Office of Educational and Civil Applications, stresses that the program is taking a "technology-push" approach to commercial applications. "We will develop the technology we need and publicize what seems commercially useful," he says. "The applications are limited only by the imagination and creativity of American companies."

But companies must first wrest the technology from the government's clutches: Despite their professed eagerness to transfer technology to the private sector, program managers have declared all SDI research "advanced development," a category that is almost always classified. "So much of the SDI research is classified," says Jerry Glen, technical director of the Laser Institute of America (Toledo, Ohio), "that it's impossible to know what its

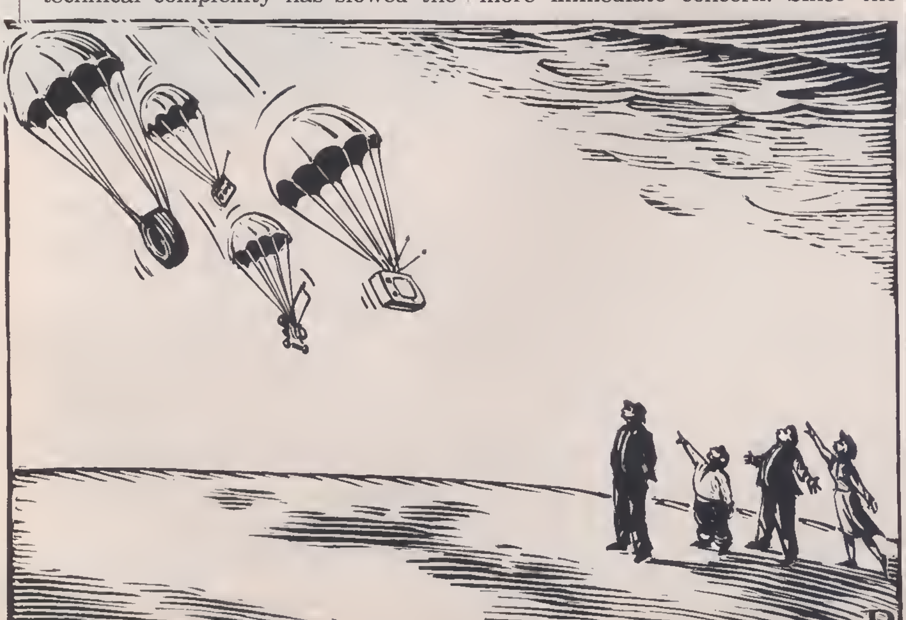
BOB DAHM

commercial usefulness will be." In addition, the Pentagon has the right to withhold unclassified technical data with military or space applications.

Even SDI work that is unclassified, released, and appropriate for commercial applications will not readily yield business benefits to firms that are not SDI contractors, says D. Bruce Merrifield, the Commerce Department's Assistant Secretary for Productivity, Technology, and Innovation, because such research is often "bottled up by bureaucratic procedures in Washington." And even the SDI contractors—major players include Boeing, TRW, Hughes Aircraft, Lockheed, Rockwell, Teledyne Brown Engineering, and LTV Aerospace—could find themselves impeded by red tape. Bobby Inman, chairman of the Microelectronics and Computer Technology Corp., contends that the Defense Department's long procurement cycle has become a major hindrance to commercialization. Defense research produced numerous spinoffs in the 1950s when the procurement cycle was four to five years, explains Inman, but with the current 12- to 13-year cycle "the U.S. loses most of the economic commercial advantage that we once obtained from the early availability of technology." Increased technical complexity has slowed the process, and so has public and congressional pressure for closer scrutiny of military projects. Although Inman would like to see the bureaucracy streamlined, the current fuss over Defense Department procurement abuses makes that politically impractical.

SDI spinoffs may face more basic problems, in that much of the technology could prove inherently unadaptable to commercialization—particularly as the program moves rapidly into its demonstration phase. "Probably 90% of SDI laser funding goes to the development of specific hardware," says laser physicist Robert Byer of Stanford University, "and most of it is extremely large and high-powered, not at all suited to commercial uses." SDI's x-ray laser research, for example, involves powering the laser with a nuclear explosion. Byer points out that Japan, meanwhile, is funding research in carbon dioxide and solid-state lasers for welding, annealing, and other industrial applications, and in semiconductor diode lasers for use in compact disc players and fiber optic communications—all areas of direct commercial potential. "We could," warns Byer, "see the demise of the U.S. commercial laser industry in the next decade."

The Laser Institute's Glen has a more immediate concern. Since the start-up of SDI, he claims, the government has introduced tighter restrictions on the export of lasers and laser technology because they now have potentially greater military value. "The export controls are hurting U.S. competitiveness," says Glen. "Our trading partners don't want to put up with the hassles of export license approval when they can buy the same kinds of equipment elsewhere without the delay."



The most fundamental misgivings about SDI's commercial potential stem from doubts about the underlying technology-push theory of innovation. This theory gives a distorted picture of the marketplace, says John Pike, a space and military policy analyst for the Federation of American Scientists. In practice, he says, SDI could actually cause a shortage of scientists and engineers in key commercial technologies that are already established. For example, it could compete for researchers pursuing civilian applications in supercomputers, gallium arsenide chips, and optical computers. Program officials dismiss this fear, claiming that SDI will encourage more students to enter these fields.

Rougeau says that by the end of this year the Office of Educational and Civil Applications will establish advisory panels to review SDI research for commercial potential. Promising research will be promoted through NASA publications at first and eventually through SDI's own publications. The SDI Organization is borrowing NASA staff to help in its technology transfer efforts, and intends to look into other ways of alerting companies to new technology. Rougeau points out, however, that the organization will spend only 5–10% as much as NASA in promoting spinoffs.

The embryonic nature of the research, together with the currently modest mechanisms for exploring commercial applications, leads even ardent SDI supporters to concede that it is still too early to predict the scale of commercial spinoff. "I expect to see products emerge," says Rougeau, "but it will take years. We have to be realistic about the timing." □

Kevin Finneran is Washington correspondent for HIGH TECHNOLOGY.

PIEZOPOLYMERS: GOOD VIBRATIONS

Pressure-sensitive films are turning up in applications from robot hands to violins

Researchers at Pennwalt, the Philadelphia-based chemical producer, are launching plastic balloons that sing. The thin plastic walls vibrate to recorded-music electrical signals carried to the balloon by thin metal wires.

Singing balloons aren't Pennwalt's weightiest new product entry, but they demonstrate the materials called piezoelectric polymers, or piezopolymers—plastic films that convert heat and pressure to electricity, and vice versa. Pennwalt's piezopolymer manager J. Victor Chatigny notes that the films have already begun to appear in a host of novel applications: transducers (sound generators and receivers) for sonar and medical ultrasound equipment, detectors that control office lighting, medical thermometers, robot tactile sensors, acoustic pickups for musical instruments, force and strain gauges, and muscle motion sensors that help the handicapped operate electronic equipment. One company even hopes to use the polymers to generate hydroelectricity.

Since their discovery a century ago, piezoelectric solids such as quartz and ceramics have been used as phonograph pickups, transducers, and spark igniters for gas stoves. (One 1983 study put the total U.S. market for all types of piezoelectric materials at about $270 million a year.) These solids are brittle, however, and difficult to make in complex shapes. Moreover, their utility in some electronic applications is limited by their crystalline structures, which keep them vibrating (rather like a gong) when only a brief vibration is wanted.

One answer to these problems came in the late 1960s, when researchers discovered that certain polymers—notably polyvinylidene fluoride (PVDF), which was then widely used in pipes, valves, pumps, and other products—also possessed piezoelectric properties. They also featured ease of fabrication, controlled-vibration properties, and resistance to shattering. Major PVDF producers now include Pennwalt (which sells the material under the name Kynar), West Germany's Solvay, and Japan's Kureha Chemical. By the mid-1970s, says Chatigny, "Pennwalt also started taking a harder look at the polymer's commercial potential."

by Gordon Graff

Because of the relative novelty of the film for piezoelectric applications, current sales (at $10–$50 a square foot, a common price for such specialty polymers) are generally estimated at only $1–2 million a year, and most analysts balk at predicting future sales. However, Pennwalt is now supplying Kynar film to several thousand customers for new-product R&D. "We expect the market for these films to reach $50–100 million within the next decade," says Chatigny.

Like all piezoelectric materials, the polymers consist of countless dipoles—regions of positive and negative charge, each pointing in a different direction—that are formed during processing. In the case of PVDF, the dipoles arise as negative charges on the fluorine atoms and positive charges on the hydrogen atoms. The dipoles are at first randomly oriented in a nonpiezoelectric structure; piezoelectricity is imparted by a process called poling, in which the dipoles are aligned by stretching and heating the plastic in an electric field.

After alignment, pressure on the film squeezes the dipoles together, causing mutual repulsion of similarly charged groups; the repulsion is propagated down the length of the polymer, causing the charges to build up at electrodes on each side of the film. Relaxing the pressure draws the charges back into the polymer, like a sponge absorbing water. Because of expansion and contraction, temperature changes have similar "pyroelectric" effects, causing the charges to be drawn in or forced out. If electrical connections are made between the metal contacts on both sides of the film, a small current is produced any time pressure to the polymer is applied or released, or whenever it is heated or cooled. Conversely, when electric charges are applied to the film surfaces, they either attract or repel the dipoles, causing the film to either stretch or contract.

Piezopolymers generate fairly high voltages; a 28-micron-thick PVDF film used in keyboards and keypads develops 3–10 volts with finger pressure. But they produce very low currents, typically on the order of microamperes. As a result, piezoelectric polymers are best suited for control and monitoring applications rather than power-handling tasks. (In large arrays, however, the polymers could conceivably be used in power generation.)

Piezopolymers could hit $100 million a year by 1995, says Pennwalt's Chatigny.

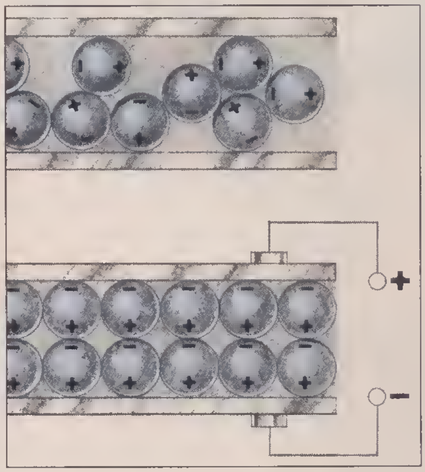
Bonneville Scientific (Salt Lake City) has built a piezopolymer-based sensor that allows a robot hand to "feel" whether a part is in the correct position, and to move it accordingly. The hand is covered by a springy rubber pad; behind it lies a flexible array of piezopolymer transducers that use ultrasound to measure the distance through the pad to the outer surface of the rubber. As the hand touches the object, the pad is deflected; the amount of deflection depends on the object's

position, and is determined by measuring the time between sound-wave generation and detection. These data are then computer-analyzed and compared with a preprogrammed "pressure profile" that corresponds to a correct position. If the data differ from this profile, a feedback mechanism directs the hand to change the part's position until the deflection is correct. The sensor was developed under government contract, says Bonneville president Allen R. Grahn, and the company plans to begin marketing the device to robotics manufacturers later this year.

Fluid-level and strain gauges, now under development by Pennwalt, are another example of piezo/ultrasound devices. The gauges consist of a small plate or other object with a piezo transducer at one end (which causes the plate to vibrate at a characteristic frequency) and a detector at the other. Mechanical or fluid pressure on the plate causes a proportionate frequency change that is picked up by the detector and correlated with the force on the object. Chatigny says that such devices will probably be used to make accurate, inexpensive industrial and consumer scales and auto fuel gauges. (To minimize the effects of sloshing in gas tanks, the sensor would be mounted in a tall, narrow tube.)

There are several medical uses of piezopolymers. At least one company (which Chatigny declines to identify) has recently introduced a system for monitoring babies at risk for the sometimes fatal condition called prolonged infantile apnea (a sleep disorder characterized by cessation of breathing for more than 20 seconds). The monitor consists of piezo film that lines the infant's sheet and is continuously charged by normal breathing motions. The signals are processed by a small computer, which can be programmed to either trigger an alarm after a period of no motion or record such periods for analysis by a physician.

Asahel Engineering (Pullman, Wash.) has developed and is now marketing devices that enable people who are paralyzed or speech-impaired to signal for help, turn switches on or off, and even operate computers. In one unit, a small strip of piezo film about the size of a Band-Aid is affixed to the forehead. The user flexes his brow in a characteristic pattern—say, three times in 10 seconds. The flexing creates electric signals that are conveyed to a computer-equipped device that activates an alarm or turns on a switch.



In a nonpiezoelectric polymer (top), the molecules' charged regions are arranged randomly. But the process called poling imparts piezoelectric properties through an applied current that reorients the molecules (bottom).

BRUCE SANDERS

A variation on this device uses the polymers' pyroelectric properties. The piezo strip is affixed under the chin so that part of it projects in front of the mouth. The user emits puffs of breath in a particular pattern, and the heat generates small jolts of electricity that can be processed to trigger a switch, alarm, or other device.

Asahel is also working on veterinary uses for polymers. One example (still under development) is an array of piezo films that detect tendon or muscle problems in a racehorse before they become hard to treat. Like humans, animals tend to compensate for such disorders by subtly changing their weight distribution. This results in abnormal pressure differentials at various points on the shoe, which are measured by the attached piezo sensors.

Another medical application of piezopolymers is a thermometer that gives a near-instant body temperature reading when placed just inside the ear. (Unlike the mouth, the ear canal is a relatively constant environment, unaffected by breathing or by hot or cold foods.) The thermometer, developed by FreMed (New Haven, Conn.), resembles a ballpoint pen. Infrared radiation inside the ear is relayed to a strip of piezoelectric film; as the temperature rises, the film produces a current that is conveyed to an attached microprocessor. The temperature is displayed on a built-in liquid crystal display.

FreMed president Jacob Fraden predicts that the device will ultimately be accurate to a tenth of a degree and sell for under $10 at drugstores. The company is also developing a piezo film unit that turns room lights on and off by detecting the body heat of the room's occupants.

Piezopolymers have also made their debut in the music industry. Raad Instruments (Toronto) has developed an electric violin that uses piezoelectric film as its acoustical pickup (the microphone attached to the instrument). The ceramic piezoelectric pickups used on most electric stringed instruments have been inadequate, says Raad president Richard Armin, because the brittle materials aren't sensitive to the subtle nuances and complex overtones of vibrating stings. As a result, he says, they cause one player's tone quality to sound pretty much like another's.

One of the special properties of the Raad violin, notes Armin, is that it can amplify sound considerably without distortion. In fact, he says, violinist Yehudi Menuhin has dubbed this instrument "the violinist's revenge," because it helps prevent a soloist from being drowned out by an orchestra. One market envisioned by Armin for the $4000 instrument is the small community orchestra, which often must amplify the sound of a limited number of players. A piezopolymer pickup is also used in a line of acoustic guitars introduced by Gibson last June.

Not as well developed is a power generation scheme for converting ocean wave energy into electricity. Small-scale tests have convinced Ocean Power Technologies (Princeton, N.J.) that such an idea is feasible. As president George Taylor explains it, a modular grid of piezoelectric film and electrodes, each component having an area of about 10 square meters, would be placed offshore about 50 feet below the surface of the water (where it would not interfere with navigation or be affected by surface storms). The force of the waves against the sides of the stretched film—about 90% of the wave energy is still present 50 feet down—would induce a high-voltage current, which would be funneled by the electrodes to a power cable and thence to an onshore power grid.

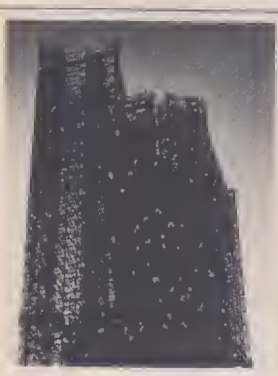
Taylor envisions a 100-megawatt

Micros at Work

Full-color reprints of the *High Technology* special report, *Micros at Work*, are now available. A comprehensive overview of the microcomputer industry, this 32-page report offers a provocative insight into the microcomputer's current slump and explains how new software and expanded applications could lead to rapid growth once again.

To order, send a check for $3.50 each to MICROS, *High Technology*, 38 Commercial Wharf, Boston, MA 02110. For information on custom reprints or orders of 100 or more, call John Titus at 1-800-372-0018. Massachussetts residents call 617-227-4700.

HT-686



If you still believe in her, help finish the job.

The Statue of Liberty-Ellis Island Foundation, Inc.
P.O. Box 1986, Dept. ABP, New York, New York 10018

LIBERTY 1886·1986

I'd like to help Save The Lady. Enclosed is my tax deductible contribution for:
☐ $10 ☐ $25 ☐ $50 ☐ $100 ☐ $500 ☐ Other $______
Please make checks payable to: Statue of Liberty.

☐ Check enclosed. Or please charge my ☐ MasterCard ☐ VISA ☐ American Express

Credit Card # ______ Expires __/__

☐ Please let me know how my company can help.

Mr.
Mrs.
Ms.
NAME (Please Print) ______ SIGNATURE (Required if using credit card.) ______

COMPANY NAME ______

STREET ______

CITY ______ STATE ______ ZIP ______

Ad Council

KEEP THE TORCH LIT®

© 1985 The Statue of Liberty–Ellis Island Foundation

ocean wave power station that would occupy several square miles. He says that such a unit could produce energy at 2¢ per kilowatt-hour (roughly a third the cost of power from fossil fuel plants and considerably less than solar power), although he admits that "there's a lot more work to be done" before it could become reality. He adds that recent financing arrangements "will let us move a lot quicker with our research."

While nearly all these schemes are based on PVDF, other piezo materials are also likely to emerge. At the Southern Research Institute (Birmingham, Ala.), chemists working with the U.S. Navy Air Development Center in Warminster, Pa., are synthesizing several polymers with built-in dipoles analogous to those in PVDF. These include some uncommon forms of nylon as well as polymers composed of amino acid building blocks.

While it hasn't yet been possible to form the amino acid polymers into films, the researchers have had more luck with the nylons. They are now subjecting these films to the poling process and evaluating their piezoelectric properties. According to Stanley Brown of the Navy's Air Development Center, potential applications of these materials include sonar transducers, impact and stress detectors, power generation units, and a variety of biomedical products.

For the time being, however, PVDF is likely to remain the mainstay of piezopolymer product development. While the bountiful list of potential outlets would seem to bode well for producers, Pennwalt's Chatigny says that "the majority of engineers are still uninformed" about the materials' properties and design opportunities. Unfamiliarity with the films, in fact, is still considered the biggest obstacle to commercialization. "We're looking at a long educational process," he says.

Given Pennwalt's growing list of customers—which Chatigny declines to identify because of the extreme secrecy surrounding many of the new developments—he's confident that the company's investment will eventually pay off. The films aren't expected to totally displace their solid counterparts, he says, "but I'm convinced that the polymers will eventually become as widely used as piezo ceramics are today." ☐

Gordon Graff, a New York-based writer, is a former senior editor of HIGH TECHNOLOGY.

ADVERTISEMENT

The MIT Press announces
A Call For ARTICLES AND PICTURES

for a major new book on ARTIFICIAL INTELLIGENCE

"The Age of Intelligent Machines"
by Raymond Kurzweil

The book, to be published in February, 1987, will be the official book of the **AGE OF INTELLIGENT MACHINES (AIM)** exhibition, the first major international exhibition on artificial intelligence. The **AIM** exhibition is sponsored by the nine leading science museums in the United States and anticipates over four million visitors during its three year national tour. Providing exhibits and support for the exhibition are a wide range of Fortune 500 companies, emerging AI companies and leading academic institutions.

The target audience of the book is the informed lay public (similar to the readership of *High Technology* magazine) as well as computer professionals. It will be published simultaneously in three languages - English (MIT Press), French (Editions Hologramme) and Japanese. The book will be a very attractive illustrated "coffee table" volume of approximately 300 pages with over 300 color pictures, including original artwork by leading artists, computer graphics and color photographs. There will also be a companion videotape involving a number of leading filmmakers. Substantial resources are being devoted to the creation of this important volume and we expect it to be a "best seller".

The author, Raymond Kurzweil, is a leading authority on Artificial Intelligence and is Chairman of the **AIM** exhibition. Proceeds from the sale of the book will go to the MIT Press and the Kurzweil Foundation, both nonprofit organizations. The Kurzweil Foundation is devoted to the application of technology for the benefit of the handicapped.

CALL FOR ARTICLES

75% of the text will be written by the author, Raymond Kurzweil. The remaining 25% will consist of approximately 20 contributed articles. A number of the contributed articles have been committed by industry and academic leaders. The majority of the 20 articles will be selected in the competition described herein. Articles submitted may be on any aspect of AI past, present or future, including techniques, approaches, social and economic impact, philosophical implications, future scenarios and predictions, and related topics. Articles should be **"alive"** - exciting and entertaining. Human interest, anecdotes and unique perspectives are encouraged. Since articles must be brief, they should be focused on a single aspect of the subject. Keep in mind the target audience of both the lay public with an interest in science and the computer professional.

Length should be in the range of 500 to 2,000 words. Submissions must include permission to publish in the **AIM** book. Pictures may be included with an article. Pictures must include complete captions, credits and permission to publish. Article author names should include titles and a brief bio. The **deadline** is **August 15, 1986.** There will be payment of $500 for each article published.

CALL FOR PICTURES

The **AGE OF INTELLIGENT MACHINES** book will include over 300 color pictures. We would like to invite the submission of photographs (color preferred, although B & W is acceptable), both current and historical; artwork; computer graphics; and illustrations covering any aspect of Artificial Intelligence - history, current work and impact, and future potential. Pictures will be selected on the basis of their relevance, excitement and interest level.

Pictures submitted should include complete captions, credits and permission to use. The **deadline** is **August 15, 1986.**

For further information, please contact Frank Satlow or Terry Ehling at The MIT Press, (617) 253-1623.
ARTICLES and PICTURES should be submitted to the author:
Raymond Kurzweil
c/o MIT Press; 28 Carleton Street; Cambridge, MA 02142

The MIT Press

PERSPECTIVES

Japan fosters technology strongholds

Japan-watchers are keeping a close eye on an ambitious three-year-old program, the "technopolis plan," aimed at giving that country an even sharper edge in the world technology market. The plan calls for creating technopolises—essentially high technology communities—throughout Japan. The program is scheduled to proceed well into the 1990s, and there are already 18 technopolises, with seven more under review.

Although some Japanese sources downplay its significance, the program could boost the nation's prodigious R&D capacity, revitalize many of its parochial industries, and relieve much of its notorious congestion.

To be officially designated a technopolis, a region must offer:

- a well-established business community, with manufacturing and distribution facilities;
- local academic resources consisting of at least one technical university as well as public and private R&D institutions.
- a congenial residential area with first-class transportation and a "mother city" of at least 150,000 people.

The Ministry of International Trade and Industry (MITI), which conceived the program in 1980, reckons that such communities will draw the financial and human resources needed to turn the regions into relatively low-cost hotbeds of technical innovation. And the jobs generated would support the so-called U-turn phenomenon, by which

Map shows the developing system of Japanese high technology communities, or technopolises. Approved sites are in lower-case type; those still under review are in upper-case. (Tokyo is included only for reference.)

DAN COLLINS

droves of skilled workers would return from the big cities to their hometowns.

The technopolis law provides a host of financial lures to foreign and domestic companies locating in approved areas, including tax breaks, low-cost loans, and subsidies (the latter totaling a modest $1.4 million last fiscal year, according to Makoto Fujioka of MITI's Industrial Location and Environmental Protection Bureau). Foreign companies might also qualify for special low-interest loans from the Japan Development Bank (JDB). Residential and industrial parks, meanwhile, are being developed by the government's Japan Regional Development Corp. (JRDC), which then offers the land at favorable interest rates. MITI and other agencies will provide technical support personnel—no small consideration in view of the agencies' high level of expertise—and help persuade top Japanese companies to patronize the technopolises.

Such incentives aside, the central government hopes to limit its role to advising and coordinating; governments at the prefectural (state) and local levels will shoulder most of the burden of attracting high tech businesses, including financing, organization, and promotion.

While the central government's financial support is relatively small, its official approval is invaluable to aspiring R&D communities. A technopolis designation is in effect a governmental seal of approval and a powerful sales tool in the competition for business investment. The program also gives local governments an instantly recognizable label with which to describe their promotional goals. Technopolis status is also an effective lubricant for obtaining municipal and prefectural funds, enlisting the aid of local businessmen, and launching publicity campaigns.

Indeed, at least part of the program's success so far is attributable to public relations. "Miyazaki Prefecture was trying very hard to get electronics companies to invest, but they still had only Oki [Electric Industry Ltd.]," says MITI's Fujioka. "But in the two or three years since they became a technopolis, they have been very successful in attracting new investment. Technopolis became the symbol, and all their policies were centered around this idea." The number of high tech businesses in technopolis areas has about doubled since the program started, according to Osamu Tsukamoto, the MITI official who until recently headed the program.

The predicted influx of U-turn workers is also materializing. "More than 100 of the 240 technical workers at our Kumamoto factory are returnees from big cities," says Ken Tohyama, general affairs executive at Tokyo Electron Ltd., a maker and importer of semiconductor production equipment. Including employees who never went to larger cities in the first place, 90% of the workers at the plant are natives of the area.

But the keystone of the program is the regional R&D plans, which call for launching or expanding prefectural research institutes geared to local industry; agricultural regions may promote biotechnology, for example, while machinery-producing areas concentrate on factory automation or robotics. Meanwhile, local technopolis foundations are encouraging cooperation between local industry and universities.

Despite the enthusiasm surrounding the technopolis concept, it's unclear whether the program contributes anything new to Japanese R&D, or simply repackages established programs. The most obvious example of the ambiguity is the dearth of new funding by the central government. "Everyone calls it the illusional program, because there's so little money involved," says one official. Nor is the technopolis designation the sole influence on corporate siting decisions. "We didn't locate [in Kumamoto] because of the technopolis, but to be close to our customers," says Tokyo Electron's Tohyama. And while access to skilled workers is also important, Kumamoto University had been producing this resource long before the technopolis came about.

Similarly, some observers are convinced that many of the technopolises were selected because substantial infrastructures were already in place. "The Hamatsu region already had Suzuki, Yamaha, and Honda factories," says JDB's Masanori Sato. "A Hamatsu technopolis was not necessary; the area was already quite developed." Other examples are Kyushu (dubbed Silicon Island) in Kumamoto Prefecture, the home of several semiconductor makers for more than a decade, and Utsunomiya, about an hour north of Tokyo by bullet train.

Nor is it easy to determine whether a region's R&D potential is the cause or the result of its designation as a technopolis. It is probably a combination of both—the technopolis merely reinforces whatever strengths already exist. "It cannot improve an area's economic situation dramatically," says Sadao Ando, international loan manager at JDB, "but it can make some difference, and it certainly can't hurt." □ ***—Robert Poe***

Engineering clinic unites industry and academe

The Engineering Clinic at Harvey Mudd College (Claremont, Cal.) is not the only example of partnership between industry and higher education, but it is clearly one of the most fruitful. Over the past 23 years, it has conducted hundreds of practical research programs for corporate sponsors.

The school currently conducts 35 projects for 25 companies, at $25,000 per project (which covers the clinic's costs). Besides industry representatives, 18 faculty members and 125 students—most of whom are getting their first opportunity to apply academic skills to "real-world" engineering problems—are now involved.

For the companies, a major benefit is attractively priced research services. "And even if we don't actually incorporate the results into our systems," says Richard F. David, engineering vice-president at Teledyne Electronics, "we get a good look at some of the country's best engineering students." The company, he notes, has spent about $200,000 on Mudd programs during the past seven years.

Students, of course, receive class

credits for participating in the clinic. "This project is supposed to take the place of one regular class, but it's a hefty class," says Mudd senior Andrea Rogers, head of a student team developing a programmable power supply for Southern California Edison. But clinic director J. Richard Phillips emphasizes the program's practical payoffs: About half the projects result in either an improvement of or an addition to the sponsor's product line, leading roughly two-thirds of the companies participating in any given year to sign up for a subsequent year. Moreover, nearly half of the 1985 clinic students were eventually hired by sponsoring firms.

Projects are selected from corporate proposals each academic year by the clinic's advisory board (composed of professors and administrators, trustees, and industry representatives); each project is conducted by four students, who are advised by a faculty member and an industrial representative (usually a project engineer). The student teams are required to make periodic presentations about their projects; these exercises not only keep the students focused on practical engineering but also help develop their communication skills.

Design programs at the Engineering Clinic are highly varied. One effort resulted in a foot-pressure transducer being designed and built for Rancho Los Amigos Hospital (Downey, Cal.). "It analyzed the gait of handicapped patients, for use in the hospital's rehabilitation program," says Terry Flower, a 1974 Mudd graduate who is now a project manager for Hewlett-Packard in San Diego. "The hospital eventually patented the analyzer, and while the school wasn't entitled to any of the potential benefits, our names did appear on the patent." Other projects now under way include an LED flat-panel display sponsored by Teledyne, which hopes to market it for use in future aircraft navigational systems, and the design and construction of a system for Douglas Aircraft to detect fatigue and stretching in control cables.

Often the students assist the sponsor not so much by developing innovative hardware as by identifying design options. For example, William E. Murray, senior staff engineer with Douglas Aircraft's Advanced Power Systems, cites a project this year that resulted in the recommendation that Douglas continue using copper in its high-performance power distribution cable design rather than change to silver materials. "They convinced us that there is only a slight difference in power loss and attenuation between the two metals," says Murray. "But using copper saves money."

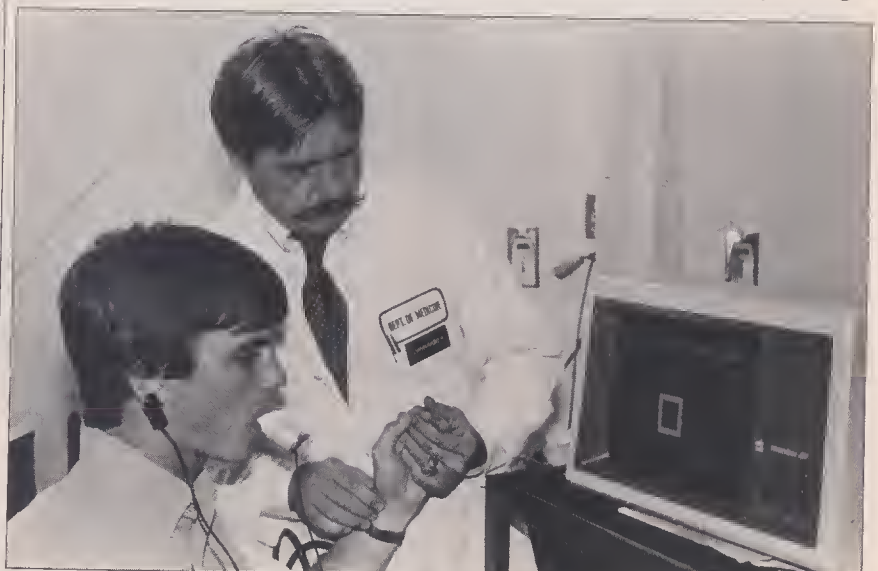
While Mudd gets high marks from Douglas for its practical, results-oriented approach, the company, like many other large corporations, has participated in research programs with several other schools. "We want more than just a relationship with a particular school," says Lars Romberg, chief program engineer at Douglas's Advanced Program Planning division. "We're investing in the future of engineering." □ ***—Ellen Alperstein***

How old is your heart?

A new computerized pulse monitor may soon allow physicians to quickly and painlessly assess the structural condition of the human heart. Developed by University of Minnesota oncologist William J. M. Hrushesky, the monitor—called the Sine-o-graph because of the sine-shaped curve it generates—measures what some researchers call the heart muscle's biological age. The two-minute test could thus provide important new information for cardiologists, primary care physicians, sports physiologists, gerontologists, and oncologists.

"Several factors cause the cardiac tissue to become less supple as we age," explains Hrushesky. "The Sine-o-graph indirectly quantifies this cardiac elasticity and alerts the physician to impending problems." Such data could previously be obtained only through the painful and hazardous process of catheterization, in which a thin tube is threaded into the heart.

Hrushesky's monitor gauges the heart muscle's elasticity (and thus its pumping efficiency) by measuring the respiratory sinus arrhythmia (RSA), a normal variation in the heartbeat that results from chest pressure changes during breathing. Children and young athletes possess such a noticeable RSA (corresponding to variations of several beats per minute) that the phenomenon is detectable simply by taking a



A patient is tested on the Sine-o-graph by inventor William Hrushesky. The device analyzes pulse rate and respiration to provide a quick and painless assessment of the elasticity (and thus the overall health) of the heart muscle.

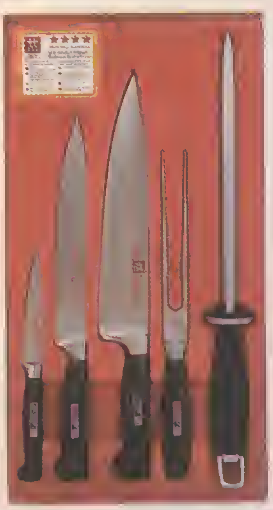
TechWorks

Create A Better Body VITALIZER II™ is the only two-person machine for home exercise. The equipment is designed so exercises can be done simultaneously. It's easy to switch from one exercise to another without disturbing your partner by making a few simple adjustments. Stay in shape together in comfort and privacy. VITALIZER II's™ progressive resistance system offers you the fastest results possible. The fully illustrated, 34-page instruction manual for proper exercise outlines 3 programs designed for specific results. °Program I — for firming, tightening and strengthening °Program II — for strength, weight loss, endurance °Program III — for muscle growth and maximum strength. VITALIZER II's™ companion exercise equipment takes the loneliness out of exercising while you build a healthier body. Although the exerciser weighs 200 lbs., it breaks down into simple components that one person can easily carry. #407050 $849.95 (55.00)

Finally, We've Found the Best. LAND LUGGAGE enthusiastically presents its 1986 collection. The president of our company was so impressed with it that he bought the entire collection for himself! Imagine the pride you'll feel traveling in confidence with the finest quality luggage available. It's made from top grain Colombian leather which is soft and flexible, yet strong and durable. So go ahead and over pack it. You'll never have to worry about damage as the interior nylon lining is waterproof and stain resistant while the exterior black leather surface is specially treated to repel moisture, stains and other traveler abuses. LAND LUGGAGE has outstanding features which travelers will appreciate...solid brass fittings won't peel, bend or break; YKK Zippers hold together under stress so your contents are secure, multiple open and zipper pockets keep travel accessories handy, and all luggage features a detachable shoulder strap for carrying ease. LAND LUGGAGE is designed tough, but with lightweight construction and top quality styling. It's one half the weight of molded hard case luggage. The traveler can expect this luggage to be a reflection of their discriminating taste. • Groomer (9"x4"x5") #407060 $38.00 (2.80) • Carry-On (21"x12-1/2"x8") #407070 $270.00 (3.83) • Softtache (17"x12"x5") #407080 $260.00 (3.83) • All Leather Deluxe (40"x24"x4") #407090 $495.00 (5.13)

Know Your Limit — DRIVESAFE The big question of the night: Can you drive home safely? DRIVESAFE electronically measures your breath alcohol concentration. Simply blow into the mouthpiece and the needle registers the breath alcohol content up to .15 per cent. It instantly gives an accurate numeric reading of your alcohol level, not an ambiguous pass/fail light warning system. DRIVESAFE uses 6 "AA" batteries and is small enough to fit in your glove compartment (5-7/16" x 2-5/8" x 1-7/16"). Be a responsible driver. With so much at stake and for peace of mind, use DRIVESAFE to know your limit before deciding to drink AND drive. #407040 $89.95 (3.57)

Henckels — The Finest Name in Cutlery Since 1731



A Cut Above J.A. HENCKELS is proud to offer their 5-piece set of TWIN FOUR STAR knives. The forged blades made of high carbon, stainless steel, have been FRIODUR® ice hardened and hand honed to provide unparalleled cutting quality. Each handle is crafted of polypropylene for extreme durability and safety. Five-piece set contains a paring knife, carving knife, chef's knife, carving fork and sharpening steel. The FOUR STAR set ensures years of matchless cutting performance. Made in Solingen, Germany. #407010 $199.95 (3.57)
Both knife and shears #407030 only $214.90 (3.57) **Save $5.00**

ORDERING INSTRUCTIONS AND GUARANTEE: Shipping and handling charge is shown in ( ). Be sure to add the item price **plus** shipping and handling charges for each item ordered to arrive at the **total price** of each item. If you are not satisfied return the article to us in original condition within 30 days, and we'll refund the price.

Shear Pleasure From cutting poultry to paper, you will find unlimited uses for HENCKELS' TWIN® Kitchen Shears. Made of high carbon, stainless steel which has been FRIODUR® ice hardened for durability, the specially synthetic compound handles are virtually unbreakable. Their sturdy, modern design provides for supreme cuts and has innovative features such as easy resharpening and the steel insert for opening screw-on caps. For every cutting task requiring scissors, the TWIN® Kitchen Shears from J.A. Henckels are all you'll ever need. Make in Solingen, Germany. #407020 $19.95 (2.80)

TechWorks
139 Grand Ave., Johnson City, NY 13790
This offer made by Spectra Products

When ordering by phone please refer to item number.

For Fast Service Call 607-770-1985
Please have Credit Card ready. Operators always on duty.
Above number is for ordering only, for customer inquiries call (607) 770-0148

Send To (Please Print)
Address
City State Zip
Enclosed is a check or money order. For $ ______ Payable to **Spectra Products**
Attach engraving instructions on a separate sheet.
We also accept ☐ Mastercard ☐ Visa ☐ Am. Express Exp. Date
Account #
Signature

Item No.	Quantity	Description/Color	Item Price	Shpg. & Hdlg.	Amt.
				Total Amount	

(Sorry, we cannot handle Canadian, Foreign or C.O.D. orders.) Please allow 30 days for delivery from our receipt of your order.
NYS Residents Sales tax will be added where applicable.

Special Advertising Section

wrist pulse. With increasing age, however, decreased cardiac suppleness makes the heart less responsive to the pressure changes and the RSA falls by an average of 10% per decade. For years, in fact, the medical profession has believed that the RSA disappears after middle age. Sine-o-graph tests now show that the RSA never disappears entirely and can be measured in people well into their 90s.

To conduct a test, the patient synchronizes his or her breathing patterns with visual prompts that appear on a computer screen while a pulse sensor (usually attached to the earlobe) collects heartbeat data for 60 seconds. The computer then calculates the heartbeat variations that accompany each breathing cycle. Because the RSA amplitude varies predictably with age, a patient's test score can be compared with those drawn from a similar age population to determine relative cardiomuscular condition.

The Sine-o-graph (which is actually a computerized version of an earlier and much more laborious technique) runs on a modified Apple IIe computer attached to the earlobe pulse sensor and a small tube that is placed in the subject's mouth. However, Hrushesky hopes to simplify the device for mass production, perhaps in the form of a microprocessor-controlled instrument that would sell for about $25. This version might also provide better graphics and faster data processing.

As an oncologist, Hrushesky initially wanted to study the effects of anticancer drugs on the heart muscle—a major concern in the case of Adriamycin and a few other compounds. On the basis of his findings, nurses at the University of Minnesota's Masonic Cancer Center regularly use the Sine-o-graph to gauge their patients' tolerances to the potentially toxic drugs.

The device is probably most promising as a screening tool for physical checkups and as a means of assessing the effects of exercise and medication on the heart muscle. But its simplicity and speed of operation—and the fact that it provides previously unobtainable information about cardiac efficiency—is also drawing the interest of cardiology researchers.

Hrushesky formed Sine-o-graph Corp. (Minneapolis) two years ago to bring his invention into the mainstream of medical practice; a market research group is now determining the potential demand for such a cardiac screening device. And while several companies want to acquire the rights to the device, Hrushesky notes that "some of them seemed to be eyeing the easy money that could be made from commercial applications such as installation in health clubs and homes—even airports. I still see the Sine-o-graph primarily as a cardiac screening device for physicians." □

—*John S. Berestka*

Emergency calls via meteor trails

Disaster strikes—phone lines are down, electricity is off, and an isolated region of the country needs emergency assistance. How can messages for help get through? When a new system proposed by the Federal Emergency Management Agency (FEMA) is completed, calls could be sent by bouncing VHF radio signals off short-lived meteor trails.

Conventional VHF radios used by police and other emergency organizations are generally limited to line-of-sight transmission—often 50–80 kilometers, depending on the terrain—which would be inadequate in the case of a large-scale disaster. However, some VHF signals can be reflected from the upper atmosphere by trails of charged particles left by meteors. The meteor trails occur 90–120 km above the earth's surface. This allows VHF signals to be sent over much greater distances—up to 2000 km, or approximately the distance between Boston and New Orleans.

Large meteors, which leave visible trails, do not occur often enough to be useful for communications, but small meteors of a millimeter or less in diameter enter the upper atmosphere at a rate of 5–8 billion per day. Although this rate varies with the time of day and the season, there are always many trails available for communications. The problem is that the meteor trails are of short duration—anywhere from a fraction of a second to a few seconds—so communications have to be sent in short bursts.

A typical meteor-burst system consists of a master station and many remote stations. The master station continuously emits a signal, called a probe, at a fixed frequency between 40 and 50 MHz; when a remote station receives the probe signal, it knows there is a meteor trail available to establish communications. The remote station then transmits a message in a burst. Once the trail disappears, another is sought; by jumping from one trail to another, a long message can be built up from many short bursts. Using this procedure, a meteor-burst system with a data transmission rate of 2400 bits per second can send a teletype-like message between stations at an average rate of 70–100 words per minute.

The remote stations used in meteor-burst networks can be portable; some are as small as a briefcase and weigh around 20 pounds. The combination of long-distance coverage and portability makes meteor-burst systems ideal for emergency use. FEMA plans to install meteor-burst terminals in each of its 10 regional centers and to install a master station at its Washington, D.C., headquarters.

Meteor-burst systems have already proved their worth: The Alaskan Meteor Burst Communication System (AMBCS) provides communications in remote locations and during periods of intense auroral activity, when normal radio communications are disrupted. It is used by the Bureau of Land Management to contact surveying teams, the Corps of Engineers to collect environmental data from remote locations, the National Weather Service to collect weather data, and the U.S. Geological Survey to collect information about water flow in rivers.

The meteor-burst communications business is growing steadily. The Collins Communications Systems Division of Rockwell International sells equipment to the military for emergency backup communications and has provided systems for remote weather-data acquisition. Vaisala (Helsinki, Finland), known for its state-of-the-art weather equipment, has developed its own system for collecting and transmitting weather data. And Meteor Communications Corp. (Kent, Wash.), which has been selling meteor-burst equipment and software since 1975, recently developed a system for the People's Republic of China to provide teletype communications between remote regions, and a system for Egypt that will be used to solve the ancient problem of monitoring the flow of the Nile River. □

—*Salvatore Salamone*

SUBSCRIBE NOW AND SAVE

☐ 1 year (12 issues) of highTechnology for just $21.
☐ 3 years (36 issues) of highTechnology for just $42.

NAME TITLE

ADDRESS APT #

CITY STATE ZIP

Subscriptions to Canada, $26; all other countries, $45 (air mail delivery).
Please allow 4-6 weeks for delivery.

4ANN8

☐ Payment is enclosed ☐ Please bill me later

highTechnology

Use this card for quick information about the products & services advertised in highTechnology

To receive information circle the reader service number appearing on each ad. Be sure to answer all questions completely. This information will help manufacturers reply more specifically to your request.

NAME TITLE

COMPANY TELEPHONE

ADDRESS

CITY STATE ZIP

Please check appropriate information:

1.) Your Function
( ) 1. Corporate Management
( ) 2. Technical Management
( ) 3. R&D Management
( ) 4. Engineering
( ) 5. Other

2.) Number of Employees in Company
( ) A. Under 50 ( ) E. 1000-2499
( ) B. 50-99 ( ) F. 2500-4999
( ) C. 100-499 ( ) G. 5000-9999
( ) D. 500-999 ( ) H. 10000 & over

3.) Your Purchase Influence
(check all that apply)
( ) 1. Recommend
( ) 2. Specify
( ) 3. Approve

4.) Type of Industry
Manufacturing:
( ) A. Electrical Equipment
( ) B. Professional/Scientific Instruments
( ) C. Transportation
( ) D. Machinery (except elec.)
( ) E. Chemicals
( ) F. Other
( ) G. Financial
( ) H. Professional/Business
( ) I. Government
( ) J. Other

1	11	21	31	41	51
2	12	22	32	42	52
3	13	23	33	43	53
4	14	24	34	44	54
5	15	25	35	45	55
6	16	26	36	46	56
7	17	27	37	47	57
8	18	28	38	48	58
9	19	29	39	49	59
10	20	30	40	50	60

( ) Please send me 12 issues of High Technology and bill me at $21.00

This card expires September 1, 1986

ackard's Spectrum
ises speed, cost-ef-
trosky. *InfoWorld.*
view of RISC tech-
npact on the micro-

38

ve., SW, Wash., DC
ublic information
(fields questions
other NASA pro-
mercial Programs,
ees NASA's efforts
nies to undertake

Space Transporta-
rtation, 400 7th St.,
(202) 426–5770.
nal Affairs. Inter-
ng the possibilities
mercial launcher

First St., SE, Wash.,
Manfredi, (202)
J.S. and overseas
ents in space.
nerce Program, Of-
essment, U.S. Con-
.0, (202) 226–2209.
y and commercial

, 955 L'Enfant Pla-
Wash., DC 20024,

nautics and Astro-
ay, New York, NY

n and Competition
ctivities. OTA-ISC-
of Technology As-
20510. A report,
s, on the policy im-
ace activity for the
e sectors.
Competitive Fron-
iness–Higher Edu-
upont Circle, Suite
(202) 939–9345. A

valve Porsche 928S V8 engine.

"Saab Turbo." *Road & Track,* Jan. 1985. Road test and description of the 16-valve, turbocharged and intercooled DOHC engine in the Saab 900 Turbo.

"Mazda RX-7 Turbo." *Car and Driver* (Ann Arbor, MI), April 1986. Test of the Mazda RX-7 Turbo, with technical analysis of its dual-port turbocharger system.

"Oldsmobile Quad 4 engine." Csaba Csere. *Car and Driver,* April 1986. Complete technical analysis and overview of the Oldsmobile Quad 4 engine, with comparative charts and graphs.

"Yahama FZ750." Kevin Cameron. *Cycle* (New York, NY), March 1985. Detailed

puter line.

"A simple design may pay off big for Hewlett-Packard" and "HP takes careful approach with new Spectrum computers." Clifford Barney. *Electronics,* March 3, 1986. Two articles on Hewlett-Packard's new line of computers.

"Compilers for the new generation of Hewlett-Packard computers." Deborah S. Coutant, Carol L. Hammond, & Jon W. Kelley. *Hewlett-Packard Journal,* Jan. 1986. Explains how RISC designs rely heavily on optimizing compilers to attain their high performance levels.

"A part of the puzzle." Ralph Emmett Carlyle. *Datamation,* March 15, 1986. An

call for acceleration of U.S. exploration and commercial development of space, from a panel of academic and corporate chief executives. $18.

Report of the National Commission on Space. Spring 1986. 490 L'Enfant Plaza East, SW, Suite 3212, Wash., DC 20024, (202) 453–8685. A study of U.S. space prospects for the next half-century.

Commercial Space (New York, NY), fall 1985. Issue examines prospects and problems for space commercialization.

"The new American frontier." Gerard O'Neill. *Discover,* Nov. 1985. Noted space entrepreneur and visionary looks at the future of space development.

wrist pulse. With
ever, decreased
makes the heart
pressure changes
an average of 1
years, in fact, th
has believed tha
after middle ag
now show that
pears entirely an
people well into t

To conduct a
chronizes his or h
with visual pron
computer screen
(usually attache
lects heartbeat
The computer
heartbeat variat
each breathing c
amplitude varies
a patient's test s
with those draw
population to de
diomuscular con

The Sine-o-gra
a computerized
and much more
runs on a modifie
attached to the
and a small tube
subject's mouth.
hopes to simplify
production, perh
microprocessor-c
that would sell
version might
graphics and fast

As an oncologi
ly wanted to stu
cancer drugs on
a major concern
mycin and a few
the basis of his fi
University of M
Cancer Center re
o-graph to gauge
ances to the poter

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 68 BOULDER, CO

POSTAGE WILL BE PAID BY ADDRESSEE

highTechnology
P.O. Box 2808
Boulder, Colorado 80321-0001

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

Business Reply Mail
First Class Permit No. 27 Woburn, MA

Postage will be paid by addressee

highTechnology
Reader Service Department
P.O. Box 2183
Woburn, MA 01888

The device is probably most promising as a screening tool for physical checkups and as a means of assessing the effects of exercise and medication on the heart muscle. But its simplicity and speed of operation—and the fact that it provides previously unobtainable information about cardiac efficiency—is also drawing the interest of cardiology researchers.

Hrushesky formed Sine-o-graph Corp. (Minneapolis) two years ago to bring his invention into the mainstream of medical practice; a market research group is now determining the

eter enter the upper atmosphere at a rate of 5–8 billion per day. Although this rate varies with the time of day and the season, there are always many trails available for communications. The problem is that the meteor trails are of short duration—anywhere from a fraction of a second to a few seconds—so communications have to be sent in short bursts.

A typical meteor-burst system consists of a master station and many remote stations. The master station continuously emits a signal, called a probe, at a fixed frequency between 40

(Helsinki, Finland), known for its state-of-the-art weather equipment, has developed its own system for collecting and transmitting weather data. And Meteor Communications Corp. (Kent, Wash.), which has been selling meteor-burst equipment and software since 1975, recently developed a system for the People's Republic of China to provide teletype communications between remote regions, and a system for Egypt that will be used to solve the ancient problem of monitoring the flow of the Nile River. □

—Salvatore Salamone

RESOURCES

Information sources for topics covered in our feature articles

Cars (general), p. 12

Contacts

Ward's Communications, 28 W. Adams St., Detroit, MI 48226, (313) 962–4433. Publisher of *Ward's Automotive Yearbook* ($110), which provides information on suppliers, and the monthly magazine *Ward's Auto World* ($35/yr), which gives updates on technology and markets.

Soc. of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, (412) 776–4841.

Motor Vehicle Manufacturers Assn., 300 New Center Bldg., Detroit, MI 48202, (313) 872–4311.

References

Automobile Handbook. Robert Bosch GmbH. Stuttgart, West Germany, 1976. Thorough, highly technical compilation of engineering and technological information on practically every aspect of the modern automobile.

"Pushing ahead in car technology." Jeffrey N. Bairstow. *High Technology,* Aug. 1985. Concise review of Japanese auto technology.

"The high-tech car hits the road." Peter Petre. *Fortune,* April 29, 1985.

"Bosch: the king of black boxes." Louis S. Richman. *Fortune,* April 29, 1985. A look at innovations from the West German automotive giant.

Little engines that can, p. 12

"Continuously variable transmissions." Ernest Raia. *High Technology,* July 1984. In-depth examination of gearless transmissions.

"Turbochargers roar into action." Carl Rain. *High Technology,* May 1983. A look at the reemergence of the turbo.

"Future auto engines: competition heats up." Carl Rain. *High Technology,* May/June 1982. A review of engine technologies.

"1985 828S." Kim Reynolds. *Road & Track* (Newport Beach, CA), Feb. 1985. Overview and analysis of the four-cam, 32-valve Porsche 928S V8 engine.

"Saab Turbo." *Road & Track,* Jan. 1985. Road test and description of the 16-valve, turbocharged and intercooled DOHC engine in the Saab 900 Turbo.

"Mazda RX-7 Turbo." *Car and Driver* (Ann Arbor, MI), April 1986. Test of the Mazda RX-7 Turbo, with technical analysis of its dual-port turbocharger system.

"Oldsmobile Quad 4 engine." Csaba Csere. *Car and Driver,* April 1986. Complete technical analysis and overview of the Oldsmobile Quad 4 engine, with comparative charts and graphs.

"Yahama FZ750." Kevin Cameron. *Cycle* (New York, NY), March 1985. Detailed description and explanation of the Yamaha FZ750 motorcycle, with emphasis on its five-valve-per-cylinder technology.

The chassis gets classy, p. 18

"Four wheel steering system with rear wheel steer angle controlled as a function of steering wheel angle." Shoichi Sano, Yoshimi Furukawa, & Shuji Shiraishi. Presented at the annual Congress of the SAE, Feb. 1986. Authors are Honda R&D engineers.

"Electronic optimum ride control, handling, height and suspension." Shinzo Totani. Presented at the Int'l Congress on Transportation Electronics, SAE, Oct. 1984. Totani is executive senior managing director of Nippondenso in Japan.

"Plastic cars hit the road." Jeffrey Zygmont. *High Technology,* Dec. 1985. A look at future car materials.

Simpler computing, p. 28

References

"High RISC factors." Stan Kolodziej. *Computerworld Focus,* April 16, 1986. A look at problems associated with introducing a new architecture.

"RISC chips." John Markoff. *Byte* (Peterborough, NH), Nov. 1984. Good introduction to RISC architecture.

"A VLSI RISC." David A. Patterson & Carlo H. Sequin. *IEEE Computer* (New York, NY), Sept. 1982. A detailed overview of RISC concepts and architecture, including tables and illustrations of RISC characteristics.

"Back-to-basics computers with sports-car speed." Stuart Gannes. *Fortune,* Sept. 30, 1985.

"Reduced instruction set computers." David A. Patterson. *Communications of the ACM* (Association for Computing Machinery, New York), Jan. 1985. Examines RISC's origins, common traits, and variations.

"Beyond RISC: high-precision architecture." Joel S. Birnbaum & William S. Worley, Jr. *Hewlett-Packard Journal* (Palo Alto, CA), Aug. 1985. A look at how RISC and other technology meshed with the design objectives for HP's new computer line.

"A simple design may pay off big for Hewlett-Packard" and "HP takes careful approach with new Spectrum computers." Clifford Barney. *Electronics,* March 3, 1986. Two articles on Hewlett-Packard's new line of computers.

"Compilers for the new generation of Hewlett-Packard computers." Deborah S. Coutant, Carol L. Hammond, & Jon W. Kelley. *Hewlett-Packard Journal,* Jan. 1986. Explains how RISC designs rely heavily on optimizing compilers to attain their high performance levels.

"A part of the puzzle." Ralph Emmett Carlyle. *Datamation,* March 15, 1986. An analysis of Hewlett-Packard's Spectrum announcement.

"RISC technology promises speed, cost-effectiveness." Mary Petrosky. *InfoWorld.* Oct. 7, 1985. An overview of RISC technology and its likely impact on the microcomputer world.

Space business, p. 38

Contacts

NASA, 400 Maryland Ave., SW, Wash., DC 20546. Dave Garrett, public information officer, (202) 453–8400 (fields questions on Space Shuttle and other NASA programs). Office of Commercial Programs, (202) 453–1123 (oversees NASA's efforts to encourage companies to undertake space enterprises).

Office of Commercial Space Transportation, Dept. of Transportation, 400 7th St., SW, Wash., DC 20590, (202) 426–5770. Anne Linnertz, External Affairs. Interagency group examining the possibilities of spinning off a commercial launcher business.

Library of Congress, 10 First St., SE, Wash., DC 20540. Arthur Manfredi, (202) 287–7076. Follows U.S. and overseas commercial developments in space.

Int'l Security and Commerce Program, Office of Technology Assessment, U.S. Congress, Wash., DC 20510, (202) 226–2209. Analyzes space policy and commercial opportunities in space.

European Space Agency, 955 L'Enfant Plaza, SW, Suite 1404, Wash., DC 20024, (202) 488–4158.

American Inst. of Aeronautics and Astronautics, 1633 Broadway, New York, NY 10019, (212) 581–4300.

References

International Cooperation and Competition in Civilian Space Activities. OTA-ISC-239, July 1985. Office of Technology Assessment, Wash., DC 20510. A report, prepared for Congress, on the policy implications of recent space activity for the U.S. public and private sectors.

Space—America's New Competitive Frontier. Spring 1986. Business–Higher Education Forum, One Dupont Circle, Suite 535, Wash., DC 20036, (202) 939–9345. A call for acceleration of U.S. exploration and commercial development of space, from a panel of academic and corporate chief executives. $18.

Report of the National Commission on Space. Spring 1986. 490 L'Enfant Plaza East, SW, Suite 3212, Wash., DC 20024, (202) 453–8685. A study of U.S. space prospects for the next half-century.

Commercial Space (New York, NY), fall 1985. Issue examines prospects and problems for space commercialization.

"The new American frontier." Gerard O'Neill. *Discover,* Nov. 1985. Noted space entrepreneur and visionary looks at the future of space development.

HIGH TECHNOLOGY CLASSIFIED

POSITIONS AVAILABLE

Scientists/Engineers--Hi-Tech. Our service is recruiting talent for high technology firms nationwide. We offer confidential career assessment. For details contact Allen Lutz, (203) 728-0021. Noctun Associates (Agency), 241 Asylum Street, Hartford, CT 06103.

Sr. Materials Scientists

Flow Industries, Inc. is a rapidly growing state-of-the-art R&D firm exploring a wide range of scientific and engineering challenges.

Our nawly established Advanced Materials Oivision is pursuing contract R&D in high temp. and structural ceramics, optical, materials and material processing. Our goal is to develop these operations into new enterprises that can offer our employeas the opportunity for equity participation.

Openings exist for senior level Scientists and Engineers who possess an advancad dagree and have experience in one of the following areas:

- Ceramic Processing
- Optical Materials
- High Temp. Materials
- Glass Science
- Solid State Chamistry/Physics
- Inorganic Synthasis
- Caramic Compositas

We offer an excellent compensation program, complete benefits, and an opportunity to work in a creative and challanging environment. Please submit your resume with cover letter to:

Flow Industries, Inc.
HUMAN RESOURCES OEPARTMENT
21414 68th Avenue South
Kent, WA 98032
Equal Opportunity Employer

OFFICE EQUIPMENT

Business Phones!! Complete Systems. Budget Prices. Free Information. (800) 334-0854 ext.534.

BUSINESS PHONE STORE! User-installable, TIE616 4 Phones, $995: (800) 328-5369.

BUSINESS PHONE STORE! User-installable, WOLV410 3 Phones, $395. (800) 328-5369.

REAL ESTATE

Repossessed homes from Government from $1.00 plus repairs/taxes. Nationwide! Also tax properties. 216-453-3000, Ext. H8036.

TWO ACRES, CHOICE LOCATION. North Suburb Chicago on State Highway. Ideal Headquarters building. 13,000 Square Feet Interior. Acre Parking. Please respond to Box #225.

TRAVEL

TAKE A BREAK. Wilderness vacation, whitewater rafting, Colorado River, Canyonlands National Park. 2 to 6 days, Brochure 1-800-DIAL WET.

FUNDS AVAILABLE

Funds available to high tech companies. Private investment and public and private stock issues. American Business Development Corporation, 5050 Poplar Street, #1420, Memphis, TN 38157.

VIDEO MOVIES

'GRAND CANYON', 2-hour spectacular helicopter exploration VIDEO. Breathtaking music. Critically acclaimed. Details FREE. Beerger Productions, 3217-V25, Arville, Las Vegas, Nevada 89102. (702) 876-2328.

PUBLICATIONS

THE IACOCCA TAPES. Six cassette album only $19.95. Free brochure. DYNAMIC ACHIEVERS ASSOCIATION, Box HT-144200, Coral Gables, FL 33114.

BUSINESS SERVICES

Government Contract Experts: Proposals—Changes—Claims—Audits. SYNERGISTIC DYNAMICS (912) 897-4764.

INCORPORATE WITHOUT LEGAL FEES! Free Booklet Tells How, Includes Forms. Call Harvard Business Services Now: (800) 345-CORP.

RESEARCH & DEVELOPMENT

'SEED MONEY' available. The Lopata Research and Development Corporation has been formed to supply 'seed money' to develop 'your dream' to commercial practice. If you have a good program, chemical, new process or materially related idea, we are willing to explore to further development with you. We have room in our program for several more projects. Our approach can be tailored to suit the individual opportunity. If you would like to discuss your proposal in more detail (do not disclose any confidential or proprietary data), please write to LOPATA RESEARCH AND DEVELOPMENT CORPORATION, Suite 202, 222 S. Bemiston, St. Louis, MO. 63105.

LASER MACHINING. CNC 4 axis prototype to production capability: custom sheet metal, plastic, tubing fabrications. Send inquiries to: Webster Tool & Die, Inc., 164 Orchard Street, Webster, New York 14580.

BUSINESS OPPORTUNITIES

DON'T BE LEFT OUT. Realize your financial dreams along with thousands of professionals nationwide. WAWRZYNEK, Box 329, N. Tonawanda, NY 14120-0329.

Be your own boss. Tremendous profits. $5.00 brings giant catalog, refundable on first order. PRESTIGE'S SPECIALTY MERCHANDISERS, P.O. Box 327, Dept. WI, Nyack, NY 10960.

EXERCISE EQUIPMENT

Better Than Jogging, Swimming, or Cycling

NordicTrack

Jarless Total Body Cardiovascular Exerciser Duplicates X-C Skiing for the Best Way to Fitness

NordicTrack duplicates the smooth, rhythmic, total body motion of XC skiing for the most effective cardiovascular exercise obtainable. Uniformly exercises more muscles than any other exercise device. Makes high heart rates easy to obtain and keeps more muscles in tone. Highly effective for weight reduction. Used by both men and women. Does not cause joint and back problems as in jogging or running. Arm and leg resistances are separately adjustable. Uses no motors and folds compactly for convenience. Used in homes, businesses and institutions.

FREE BROCHURE 1-800-328-5888 MN 612-448-6987
PSI 141G Jonathan Blvd. North, Chaska, MN 55318

ANTIQUES

ANTIQUE SCIENTIFIC & Nautical instruments, microscopes, globes, telescopes, illustrated catalogs. Introductory subscription $4. Historical Technology, Inc. 6S Mugford Street, Marblehead, MA 01945.

PATENTS & INVENTIONS

MAKE MONEY AS AN INVENTOR. Government helps get you started. Rush $3.50. YORK ENTERPRISES, 1252-HT Laurel, St. Paul, MN 55104.

Inventors! Call AIM–We present ideas to manufacturers. For free Information kit, 1-800-225-5800.

Inventions, ideas, technology wanted! Call free 1-800-528-6050. Canada, 1-800-528-6060. X831.

INVENTORS! Can you patent and profit from your idea? Call AMERICAN INVENTORS CORPORATION for free information. Over a decade of service. 1-800-338-5656. In Massachusetts or Canada call (413) 568-3753.

NEW IDEA? American Patent in Washington, D.C. will assist you through RESEARCH and DEVELOPMENT! Free Kit—1-800-257-7880.

EDUCATION

Bachelor's, Master's, Doctorates. Guide to Colleges offering non-residential degree programs through independent home study. Accredited, economical, accelerated programs. Credit given for prior accomplishments and work experiences. Free detailed brochure. Write: Dr. John Bear, P.O. Box 11447-HT, Marina Del Rey, CA 90295.

A UNIVERSITY DEGREE CAN UNLOCK YOUR EARNING POWER. Complete your B.A., M.B.A., Ph.D., or J.D. Credit for Occup./Prof. experience. No classroom attendance required. Registered with California Committee of Bar Examiners. KENSINGTON UNIVERSITY, 330 N. Glendale Avenue, Glendale, CA 91206. In California (800) 421-9115, ext. 38. Other States, (800) 423-2495, ext. 38.

COLLEGE DEGREES through Home Study!!!...Accredited Bachelors, Masters, Ph.D's...Free Facts Revealed. Careers-HT6, Box 470886, Tulsa, OK 74147.

ALL REPLIES TO BOX NUMBERS
that appear without an address should be sent to:
HIGH TECHNOLOGY MAGAZINE
38 Commercial Wharf
Boston, MA 02110

FOR MORE INFORMATION ON *HIGH TECHNOLOGY* CLASSIFIED
Write to *HIGH TECHNOLOGY* MAGAZINE, 38 Commercial Wharf, Boston, MA 02110-3883. Or call Linda Conti at (617) 227-4700

TECHSTARTS

BioTechnica International:
CASHING IN ON GENES' VERSATILITY

Because genetically engineered organisms can be useful in a wide variety of industries, BioTechnica International has projects under way in areas ranging from healthcare to specialty chemicals. The company conducts much of its R&D, based on proprietary recombinant DNA techniques, under contract to corporate clients such as Heinz, Monsanto, Seagram, and Upjohn. Projects include making microbes that produce artificial sweeteners, animal feed additives, and pesticides; improving yeast strains used in baking, brewing, and wine making; producing bacteria that convert atmospheric nitrogen into a natural fertilizer; creating crop species resistant to herbicides; and developing a DNA probe to detect periodontal disease. The company has established operations in the U.K. and Canada and a U.S. subsidiary for developing diagnostic products.

Financing: $5 million in venture capital from private investors. $7 million (net) from a 1983 public offering by D. H. Blair of 880,000 shares at $8.75 per share. $4 million from a 1984 sale of 500,000 shares of stock to Seagram. The OTC stock symbol is BIOT.

Management: The company was founded by a group of Harvard, Princeton, and MIT biologists, and John Hunt (chairman and CEO), previously associate director of Princeton's Institute for Advanced Study. Norman Jacobs, president and COO, was cofounder of the Amicon division of W. R. Grace. Ralph Hardy, vice-chairman, headed life sciences R&D for Du Pont.

Location: 85 Bolton St., Cambridge, MA 02140, (617) 864–0040.

Founded: June 1981.

BioTechnica is applying genetic engineering to improve products from beer to beans, says CEO John Hunt.

Digital Transmission Systems:
PUTTING DATA ON MICROWAVE

Today's telecommunications carriers are struggling to forge networks from an assortment of analog and digital equipment. Analog microwave links, for instance, still exist in some networks that include high-speed digital lines. For carriers in this situation, a less expensive alternative to buying digital microwave gear might be to install a modem that processes high-speed digital signals—allocating them to a band ordinarily used for voice communications—so that they can be sent over analog channels. Digital Transmission Systems (DTS), which has an $8 million contract to supply this type of modem to MCI Communications, competes with such companies as Karkar Inc. and the Collins division of Rockwell International.

Financing: Venture capital in the amount of $5 million from Advanced Technology Development Fund, Olivetti Realty, Welsh Carson Anderson & Stowe, Glenridge Associates, and South Atlantic Venture Capital.

Management: The eight founders defected from Scientific Atlanta, a maker of satellite and microwave communications gear, where Bill Brinegar (chairman and president) headed a satellite product development team, Mickey Hudspeth (VP of marketing) was a marketing director, Jim Chamberlin (director of engineering) was an engineering manager, and Craig Sandel (operations and financial manager) was operations manager for the satellite communications division.

Location: 1000 Miller Court West, Norcross, GA 30071, (404) 448–3329.

Founded: January 1984.

Crystal Semiconductor:
ANALOG CHIPS CONTROLLED BY DIGITAL BRAINS

Analog integrated circuits are difficult both to make and to use because they need a great deal of fine-tuning, even after they're installed in equipment. But Crystal Semiconductor claims that adding digital control circuitry makes its analog chips less tricky to manufacture and test; it also permits features such as continuous self-calibration. The company mixes these digitally controlled analog circuits with a selection of ordinary digital logic and memory blocks to design chips tailored to customers' specialized needs in such areas as telecommunications and factory automation. Among its competitors in the custom analog chip market are Micro Linear and Telmos.

Financing: $11.2 million in venture capital from investors including Berry Cash Southwest Partnership, Republic Investment, Hambrecht & Quist, Interwest, Hill Partnership, Sevin Rosen Bayless Borovoy, Kleiner Perkins Caufield & Byers, and Rho Management.

Management: James Clardy, founder, president, and CEO, was Harris Semiconductor's VP in charge of overseas operations. Michael Callahan, cofounder and VP of engineering, was a design engineer for Mostek. Allan Hamilton, VP of marketing, was a marketing manager for Intel.

Location: 2024 E. Saint Elmo Rd., Austin, TX 78744, (512) 445–7222.

Founded: October 1984.

PRINTED CIRCUITS REBOUND

Vendors enjoy brisker sales as the computer market recovers

The multilayered printed-circuit board industry has undergone a cyclical growth rate that generally paralleled the pattern of computer sales in recent years. In 1985 the industry turned in a dismal performance; its revenues of $3.8 billion were 25% lower than those in 1984. However, sales this year should climb to $4.4 billion, according to Fidelity Investments (Boston). As computer markets recover their strength, a 15% average annual growth rate is projected for printed-circuit board sales over the next three to five years, with the leading firms exceeding 25% during this period.

The boards were traditionally single-sided products containing the microchips that form the "brains" of a computer. Over the past few years, laser technology has been used to print circuit patterns on smaller boards containing four to eight layers of circuitry. This technique enhances computer speed by increasing the number of chip connections and shortening the distance between them. Most computers are now configured to use such multilayered boards.

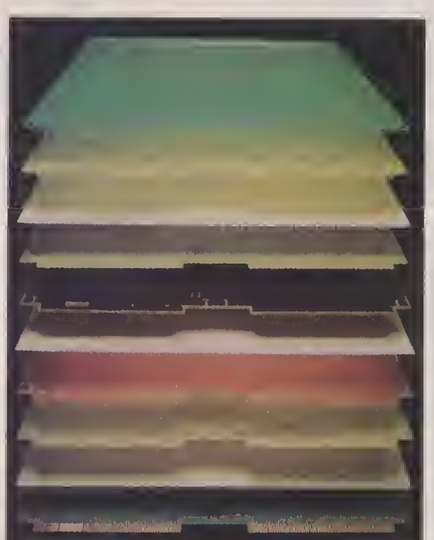
The added complexity has led to a significant change in the circuit board industry. Single-sided boards were made predominantly by computer companies themselves. But IBM, DEC, and other manufacturers have increasingly turned to independent vendors as a source of multilayered boards. A primary reason for this shift is that board production has become a highly specialized task that is no longer easy to carry out with in-house facilities. Constructing a plant is expensive—$10–15 million—as is maintenance, and the technology of designing and producing circuit boards is continually being updated. Computer companies can also cope more flexibly with changes in demand for their products by using outside vendors for board fabrication.

by Mark Boyer

Half of the revenues for 1984 sales went to such vendors; by 1990, independents could control up to 70% of the industry. Three such companies well positioned to take advantage of increasing demand are Altron (Wilmington, Mass.), Advanced Circuits (Minnetonka, Minn.), and Hadco (Salem, N.H.).

Altron (OTC: ALRN) produces complex six-, eight-, and ten-layer boards for such firms as Burroughs, Gould/Modicon, DEC, Data General, and Apollo. Altron recently completed a major expansion in Puerto Rico that will significantly increase its plant capacity while putting its products closer to the assembly facilities of some of its major customers. Favorable tax incentives offered by Puerto Rico should also lower the overall tax burden imposed on Altron's corporate earnings.

Revenue in 1985 is estimated at $30 million, profits at $1.6 million, and earnings per share at 50¢. In 1986 revenues should reach $35 million, with $1.3 million in profits and 40¢ earnings per share. The drop in profits and earnings is due to the company's absorption of increased overhead costs from plant expansion.



A multilayered printed-circuit board produced by Hadco.

Advanced Circuits (OTC: ADVC) has a strong base as a supplier of boards for computers used in F-16 fighters and other military applications, which comprise about one-third of the company's market. Because of the military's stringent requirements, the company is at the forefront of printed-circuit board technology. Its products incorporate such advanced features as highly dense circuitry, with line widths and spacing of 4–8 thousandths of an inch; seven to 22 layers of circuitry; and specialty materials such as Duroid and Teflon that can cope with temperature extremes.

In 1985 the company demonstrated great strength, with 30% growth in revenue despite a depressed market for the industry as a whole. Advanced Circuits chalked up $57.6 million in revenues and $4.5 million in profits, for earnings per share of $1.16. High R&D costs and equipment expenses are expected to cause a drop in 1986 profits to $1.5 million and in earnings per share to 35¢, in spite of a revenue increase to $70 million.

Hadco (OTC: HDCO) is the second largest independent producer of printed-circuit boards. Hadco is a major supplier to the minicomputer industry and was thus particularly affected by the downturn hitting such important customers as DEC and Wang. Hadco responded to the slump in minicomputer sales by paring expenses through a cut in its labor force and by earning a profit on the sale of Lamination Technology, a subsidiary that manufactures the inner layers of the boards. By making these moves, the company should be in a good position to return to profitability as its customer base recovers.

In 1985, revenues were $91.5 million, with a small profit of $342,000 due in part to the one-time gain from Lamination's sale; earnings per share were 3¢. Revenues could reach $100 million this year, with losses of $3 million and a 25¢ loss per share. □

Mark Boyer is manager of the Boston-based Fidelity Select Technology Portfolio and Fidelity Select Electronics Portfolio.

Views of Northern Ireland rarely seen in the media.

"The processes developed here are saving us millions of dollars worldwide..."

Ernie Chilton, General Manager,
AVX Corporation, Coleraine.

AVX Corporation, Coleraine, Co. Londonderry.

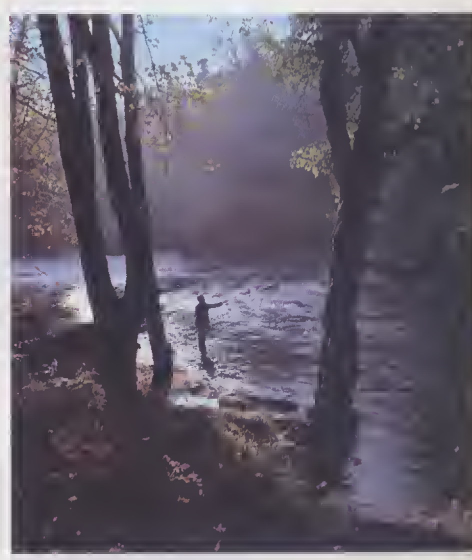
A REMARKABLE high-technology success story in Northern Ireland is told by AVX, the world's largest manufacturer of multi-layer capacitors.

Three years after setting up in Coleraine in 1978, technology was being exported back to plants in New York, South Carolina and Japan– while unit costs were being reduced by 20% a year.

"The fact is we've been amazed at the diversity of talent here" adds Dick Rosen, Senior V.P. based at Great Neck, N.Y.

These are the kinds of facts that have impressed the many North American companies who operate profitably in Northern Ireland.

We'd like you to have more facts. Call or send your business card to Michael Maguire at the address below.



River Roe, Co. Londonderry.

Northern Ireland
Judge us on the facts

Industrial Development Board for Northern Ireland,
British Consulate General, One Sansome St., Suite 850, San Francisco CA 94104 (415) 981-3030

IDB Northern Ireland

Circle No. 31 on Reader Service Card.

The ITT XTRA XP desktop personal computer

You can't buy time.

Long before Queen Elizabeth I, man began his quest to hoard that most precious and elusive of commodities. Time.

He can only make better use of the few hours he already has.

Hence, the development of today's business computer.

The ITT XTRA™ XP. Our crowning achievement.

By matching memory to the muscle of the Intel 80286 microprocessor, we're able to achieve "no wait states."

Processing never pauses for slower memory.

Making the ITT XTRA XP thirty percent faster than the IBM AT. And fully XT-compatible.

Giving you speed and flexibility.

Because, being a corporation of many businesses, we're in a unique position to better understand what you need to grow.

Today, as well as tomorrow.

	ITT XTRA XP	COMPAQ 286	IBM PC/AT
Lotus 1-2-3	11sec	13sec	15sec
dBase	36sec	52sec	56sec
FormSort	52sec	1min 5sec	1min 10sec

All comparisons are for purposes of illustration only. User's application performance is dependent on application.

A moment's investment today can pay off royally tomorrow.

Call (800) 321-7661. In California, (800) 368-7300.

And call quickly. Every moment wasted is a potentially profitable moment you'll never possess again.

ITT
PERSONAL COMPUTERS

BECAUSE TIME IS THE ULTIMATE BOTTOM LINE.

© 1986, ITT Information Systems. IBM, PC/AT and PC/XT are registered trademarks of International Business Machines. Intel 80286 is a registered trademark of Intel Corporation. Compaq 286 is a registered trademark of Compaq Computer Corporation. Lotus and 1-2-3 are registered trademarks of Lotus Development Corporation. dBase is a registered trademark of Ashton-Tate.

Circle No. 24 on Reader Service Card.